CALSTART

A California Non-Profit Consortium Developing Advanced Transportation Technologies

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

ELECTRIC AND HYBRID ELECTRIC VEHICLE TECHNOLOGIES

COOPERATIVE AGREEMENT MDA972-95-2-0011 and Modifications through P00011

QUARTERLY REPORT
July 1 to September 30, 1997

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Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

TABLE OF CONTENTS

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

TABLE OF CONTENTS

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

TABLE OF CONTENTS

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

RUNNING CHASSIS II

Project Manager: ***Amerigon Incorporated***
CS-AR94-01

Amerigon has completed the Running Chassis II program. Despite encountering some delays in the schedule, Amerigon completed the work and met the original objectives of the program.

As the final report (see Appendix) indicates, Amerigon had the four following major objectives for the Running Chassis II program:

1. Design, fabricate, and test a low-cost EV (known as the REVA);
2. Design, fabricate, and test a high-end EV for an OEM level customer;
3. Test and compare steel and aluminum chassis' in the REVA; and
4. Design, fabricate, and test a production drive train for the REVA.

These objectives were all met. Some of the key findings and accomplishments are highlighted below:

- The benefits of an aluminum chassis on a very small vehicle are not significant given the over-all weight of the chassis as a percentage of the vehicle weight (batteries included).
- A rugged, production ready integrated drivetrain was designed and produced.
- The initial prototype high-end EV was designed and developed and served as the basis for 47 additional prototypes;
- Several low-cost EVs were produced and field tested;
- In shaker tests, Amerigon completed over 200,000 kilometers of city driving on its REVA.
- Amerigon identified and after testing, found a suitable high quality vacuum forming process to manufacture low cost plastic body panels.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

RUNNING CHASSIS II

Project Manager: ***Amerigon Incorporated***
CS-AR94-01

In addition to the delays in the schedule (about eight months behind), Amerigon also found that the program was more expensive than originally anticipated. Both with the REVA and the high-end EV, Amerigon was forced to make design changes which resulted in delays and unanticipated expenditures. Amerigon had hoped to complete the program for a total of $1.42 million, but instead spent nearly $4 million. Consequently, instead of matching the $700,000 in DARPA funds with $720,000 in their own funds, Amerigon provided approximately $4 million in matching funds.

At this point, Amerigon has not finalized plans to move either the integrated drivetrain or the vehicle into production. Amerigon continues to negotiate with potential strategic partners to produce both products, either separately or collectively. Amerigon reports that it continues to have difficulty in its dealings with the Indian Government, its local partner in India, and its financial investors. Amerigon indicates that the central issues with these entities revolve around technology license rights, management and control, and other business concerns.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

RUNNING CHASSIS II

Project Manager: *Amerigon Incorporated*
CS-AR94-01

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Initiate work	200,000	460,000	1	11/14/95	11/21/95		75,000
2	Complete breadboard designs of drive train, running chassis, steel space frame	175,000	200,000	2	12/31/95	12/15/95		103,222
3	Fabricate EV4 & BEV prototype parts. Complete build of EV4	125,000	0	3	3/31/96			270,000
4	Complete all BEV tests. Revise tools for EV4 and BEV	40,000	15,000	4	6/30/96	7/8/96		
5	Complete build EV4. Complete EV4 vehicle tests.	0	0	5	9/30/96			
6	Complete and begin tests 1st productionized drive train.	0	0		12/31/96			36,000
7	Complete finite element Analysis. Complete design BEV running chassis.	0	0		3/30/97			144,000
8	Complete build/test 4 alumn BEV's w/o body panels – 2 w/welded & bonded frames. Build/test 5 productionized drive trains. Complete comparative chassis analysis and final report.	160,000	45,000	6	6/30/97			
		700,000	**720,000**				**4,098,410**	**628,222**

Match funds were not fully reported during the project. Byron Kwan, Controller, closed the project accounting records with Amerigon's costs at $4,098,410.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HYBRID ELECTRIC BUS DEMONSTRATION

Project Manager: ***Capstone Turbine Corporation***
CS-AR94-06

The CARTA hybrid bus equipped with the Capstone turbine is currently in service in Chattanooga. The bus includes a Nartron advanced electric air conditioning system, a Solectria 140 kW drive train and a Fulmen 192 amp-hour, 324 volt battery set. CARTA is very pleased with the bus and reports that the riders seem to be unaware of any difference between the hybrid and the other electric buses. Several visitors have asked, "When will the turbine start?" when the MicroTurbine is operating.

The bus has been transported to several other locations for demonstrations:

- Denver Economic Summit and Advanced Vehicle Showcase - Bus was used to transport summit staff members and to transport National Renewable Energy Laboratory guests from Denver to the NREL facility in Golden.
- Washington DC for the Conference on Changing Climate hosted by Vice President Gore
- Baltimore Maryland for the Cities For Clean Air Conference

Visitors to Chattanooga from the General Services Agency and the Electric Power Research Institute reported that they were very impressed.

<u>Third Quarter 97 Accomplishments</u>

The following activities were completed during the last quarter:

- Operation of the hybrid bus as part of the electric fleet in Chattanooga continued
- Operation with the electrically driven air conditioning system was verified
- Power management algorithm revised to improve mileage
- System integration issues were resolved
- Acoustic signatures were measured
- Demonstrations of the hybrid bus were successful

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HYBRID ELECTRIC BUS DEMONSTRATION

Project Manager: ***Capstone Turbine***
CS-AR94-06

The hybrid bus is used in regular daily service. Typical operation is to run the bus with the turbine until the fuel is used and then to run the remainder of the shift with batteries.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Initiate Work	40,000	40,000		8/30/95	12/15/95	112,811	36,000
2	Vandenburg Combustor/Monolith Test rig	102,500	102,500		12/31/96	1/11/96	102,932	92,250
1	Hardware/Electrical Design	50,000	50,000	1	12/31/96	1/11/97	50,000	50,000
2	Vehicle Integration	82,000	82,000	2	3/30/97	3/30/97		
3	System Integration	20,000	20,000	3	6/30/97	3/30/97	107,310	90,000
4	Final report	7,500	5,000	4	9/30/97			
	TOTAL	**300,000**	**300,000**				**373,053**	**268,250**

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HEAVY-DUTY HYBRID ELECTRIC VEHICLE EMISSIONS STUDY

Project Manager: ***Natural Resources Defense Council***
CS-AR94-07

During this quarter, National Resources Defense Council (NRDC) efforts focused on review of material prepared by its technical subconsultant, Acurex. NRDC continued its work to edit draft report chapters and prepare the policy analysis and recommendations portion of the report.

NRDC also completed contract negotiations with Acurex for the preparation of the study evaluating the economics of hybrid electric vehicle applications in truck and bus fleets. Under this contract, Acurex will address such issues at comparative engine costs, maintenance expenses, fuel economy and engine longevity in order to estimate the internal benefits of various technologies. Acurex will prepare a spreadsheet model to evaluate capital, fuel, facility and operating costs for heavy duty vehicle operations.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Refine study design.	20,000	20,000	1	8/1/95	12/30/95	13,500	
2	Data collection	16,000	16,000	2	11/1/95	9/30/96	16,000	
3	Data Evaluation	16,000	16,000	3	2/1/96	12/30/96	23,500	63,000
4	Scientific review	16,000	16,000	4	5/1/96			
5	Draft study	16,000	16,000	5	8/1/96			
6	Final report/study	16,000	16,000	6	11/1/96			
	TOTAL	**100,000**	**100,000**				**63,000**	**63,000**

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

PROGRAM MANAGEMENT AND ADMINISTRATION

Program Manager: CALSTART

During this quarter, CALSTART worked with DARPA to add two significant new programs to this contract. The Engine Corporation of America (ECA) was placed under contract to develop a Heavy Fuel Injector for use in an engine that could be used as an auxiliary power unit in a hybrid electric vehicle (HEV) or a power source for an unmanned airborne vehicle (UAV). In the same contract modification, CALSTART also developed a new program with FEV Engine Technology to assess various engine systems for uses in HEVs and UAVs. Among the engine systems to be analyzed will be the ECA engine.

From July through September CALSTART spent a considerable amount of time with DARPA program management to further refine and develop the FY97 program, as well as the re-allocation of existing RA94 funds. On July 15, 1997, CALSTART's President and CEO Mike and Executive Vice President met with DARPA's John Gully and Robert Rosenfeld in Arlington, VA to discuss the FY97 program and the re-allocation of RA 94 funds. Final agreement was reached at the end of the quarter on both the FY97 and RA94 programs were developed.

In anticipation of the approval of FY97 funding, the project team for the General Motors Advanced Technology Vehicle (GM-ATV) High Power Charging System met at the GM-ATV facility in Torrance in late July to begin discussions on the project. On August 6, the team met at Southern California Edison's Whittier Service Center in Santa Fe Springs to review the site and finalize decisions on where to place the fast-charging station. Compliance with the Americans with Disabilities Act (ADA) regulations was discussed. GM ATV informed the team members present that they had made arrangements to ensure that the unit was ADA compliant. CALSTART provided information on the kinds of data that should be collected and reported on during the course of the project. Subsequent meetings were scheduled for subsequent months.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

PROGRAM MANAGEMENT AND ADMINISTRATION

Program Manager: ***CALSTART***

	Milestones	DARPA	MATCH	QTR	DATE DUE	COMPLETE	DARPA FUNDS EXPENDED
94	Program Management	369,000					369,000
	CS-AR94-08	369,000	0				369,000
95	Program Management CALSTART	203,394					203,394
	CS-AR95-99	203,394	0				203,394
96	Program Management CALSTART	188,502					116,983
	CS-AR96-10	188,502	0				116,983
Mod 9	Program Management CALSTART	124,500					49,500
	CS-AR97A-99	124,500	0				49,500
Mod 11	Program Management CALSTART	50,000					10,000
	CS-AR97A-99	50,000	0				10,000

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

NAVAL AIR STATION ALAMEDA: PROJECT HATCHERY NORTH

Project Manager: ***CALSTART***
CS-AR94-09A

FINAL REPORT: CALSTART Project Hatchery Alameda

The Final Report is included in the Appendix. Highlights are given below.

1. **Introduction** The objective of this project was to establish a self-financing business incubator for advanced transportation technologies at NAS Alameda. Funding was used to partially defray the start-up costs of Project Hatchery Alameda, as the incubator is called. Specific activities funded included:
    1) Develop a business plan
    2) Identify potential sponsors to donate resources and equipment
    3) Market incubator and recruit start-up businesses
    4) Develop service provider network for incubator companies

2. **Accomplishments** All of the activities identified were accomplished within schedule with the funds provided and matching funds from CALSTART.

3. **Deviations to Plan** The stated objectives were achieved. Deviations to the originally proposed plan included expansion of tasks to include identification, validation and negotiation with Navy and Re-use Authority for a vehicle test track accessible from Hangar 20, to be used under CALSTART management for clean fuel vehicle R, D & D. Planning and execution of a trial Electric Vehicle Exposition for local and regional media and the general public was also completed. Results were positive: enough to warrant proceeding with a complete International EV Expo at Alameda next year, intended to be a revenue source for PHA operation as is the test track. This also fits into the other part of this funding package: NAS Cluster Planning. Additional detail will be provided in that final report.

4. **Projections** There are no events identified that will negatively affect the project goal of establishing an advanced transportation technology business incubator at the former Alameda NAS. This has been achieved. The alternatives that expanded project scope: test track and Annual Exposition, have already been identified. These will be pursued so long as they provide additional on-going sources of revenue.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

NAVAL AIR STATION ALAMEDA: PROJECT HATCHERY NORTH

Project Manager: *CALSTART*

CS-AR94-09A

FINAL REPORT: CALSTART Project Hatchery Alameda

The Final Report is included in the Appendix. Highlights are given below.

5. **Financials** The project was completed within a budget of $150,000 in DARPA-provided funds and CALSTART-generated matching funds, which were indicated by financial statements to be slightly over $257,000. No additional funding was requested or received.

6. **Conclusions** The impact of this project has occurred in two distinct areas: 1) Successful implementation of the first civilian re-use of the closing Alameda NAS; 2) Support for the start-up and growth of a business incubator for emerging companies working on advanced transportation technologies or services. Project Hatchery Alameda has demonstrated the capacity for this type of business incubator to be self-financing at certain definable levels and mixes of occupancy. While these levels have been demonstrated and are achievable, two cautionary elements have been identified: 1) the apparent requirement for a sustainable marketing, recruitment, and screening plan that does not require large time commitments from a permanent staff of 1.5 FTE; 2) a properly functioning technology incubator is penalized for its success in moving companies into the marketplace by an immediate gap in cash flow. This argues for some level of sustained sponsorship by stakeholders in the process and, in over a year of experience, we have discovered no other incubator without such outside support to help fill the cash flow gaps. This support usually comes from the community, or industry segment, which benefits from the positive economic impact of the incubator tenants and "graduates". Project Hatchery Alameda will continue at least through the term of its lease with the U.S. Navy and ARRA.

MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	DARPA FUNDS EXPENDED
Hatchery North	150,000	257,000				150,000
	150,000	257,000				150,000

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

NAVAL AIR STATION ALAMEDA: CLUSTER PLANNING

Project Manager: CALSTART
CS-AR94-09B

FINAL REPORT: NAS Alameda Cluster Planning (DARPA RA94 Mod 3)

The Final Report is included in the Appendix. Highlights are given below.

1. **Introduction** CALSTART was tasked and funded to plan for an advanced transportation business cluster at NAS Alameda. The specific objectives delineated for CALSTART in this program were:
   1) Work with other organizations to develop a cluster of advanced transportation (AT) activities at the Alameda Naval Air Station.
   2) Try to recruit other AT firms to locate at the NAS.
   3) Encourage Project Hatchery Alameda (PHA) firms to grow and expand into their own facility at NAS Alameda.

2. **Accomplishments** Specific items accomplished under this program are recited below in response to the task statement. They include:

   1) Assessment and identification of viable office and industrial facilities at the NAS.
   2) Development of marketing materials and purchase of necessary equipment
   3) Development of cluster outreach program
   4) Identification and mobilization of additional regional resources
   5) Create strategic partnerships
   6) Facilitate lease arrangements at NAS
   7) Integrate effort with other CALSTART information programs

3. **Deviations to Plan** As noted in Section 2, the specific activities have been accomplished or addressed. The requirements for a streamlined leasing and facility re-use process have been identified but are beyond the authority of CALSTART to implement. While it was anticipated that our experience as the first civilian lessee at NAS would create a template for future use, this has not been the case.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

NAVAL AIR STATION ALAMEDA: CLUSTER PLANNING

Project Manager: CALSTART

CS-AR94-09B

FINAL REPORT: NAS Alameda Cluster Planning (DARPA RA94 Mod 3)

4. **Projections** Events that can affect project goals are not primarily technical. Problems in realizing NAS status as an AT hub are likely to be based in perceptions by the business community or slowness to react positively by existing agencies and institutions. The economic opportunity message has been broadcast by CALSTART. It needs to be carried by other stakeholders in the future. Alternatively, CALSTART could be funded to continue the work that it has been doing with the benefit of the valuable experience gained to date. Initially, ours was the only focused base re-use plan. Other plans for very mixed industrial and social re-use of the NAS may also dilute the impact of the AT center message.

5. **Financials** The project was accomplished within budget. The grant funding enabled this effort to happen. An industry focus for base re-use, for the City of Alameda, and for the East Bay region would not have happened without this support. This project created a distinct and unique identity, both with the agencies identified and the general public. There were no cost overruns.

6. **Conclusions** Funded effort on this project has been completed. Impact of the project has been to create an awareness that the former NAS Alameda is being re-established in a civilian role as a center for the AT industry. It appears that the first positive results of this effort will be in the form of transportation companies that are outgrowing the PHA incubator and being retained at base locations. CALSTART's facility has acted as a magnet for at least 20 firms to locate at the now closed base.

   Unless there is a funded extension of the CALSTART effort, the planning for an AT cluster must be done by the City as part of its EV Model City Plan. A parallel and likely scenario is the steady transition of start-ups through PHA to commercialization, given an operating environment that supports retention on-base.

   Reports on the evolution of NAS Alameda towards an AT technology hub are attached.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

NAVAL AIR STATION ALAMEDA: CLUSTER PLANNING

Project Manager: CALSTART
CS-AR94-09B

FINAL REPORT: NAS Alameda Cluster Planning (DARPA RA94 Mod 3)

MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	DARPA FUNDS EXPENDED
CALSTART NAS Planning	250,000					250,000
	250,000	0				250,000

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ELECTRIC AND HYBRID ELECTRIC VEHICLE DATA ACQUISITION SYSTEM

Project Manager: ***CALSTART***
CS-AR94-12

No significant developments to report this quarter. The following is the status of the vehicles for which we hope we will be able to collect data from:

AVS Bus w/Capstone Turbine: During the next quarter we anticipate having more technical data from Capstone to convey to DARPA.
ISE Hybrid Electric Prototype Truck: Not yet operational.
UC Davis Hybrid Electric Vehicle w/Moller Rotary Engine as APU: Operational but still awaiting delivery of Bolder batteries.
Amerigon's REVA: See Running Chassis II section and final report.

	MILESTONE	DARPA	MATCH	DATE DUE	COMPLETE	DARPA FUNDS EXPENDED
1	Feasibility Study	50,001		9/30/95	9/30/95	16,271
2	Schematic /housing for keypad/display	16,271		12/31/95	12/31/95	9,957
3	Establish Internet Connection	20,608		3/30/96	2/96	20,608
4	Hardware Test Box for Analog/digital boards	54,077		6/30/96	5/96	54,077
5	DC Converter Schematics Build Prototype.	16,666		9/30/96	12/96	21,700
6	Second PCB Testing CDAS and Installation	51,750		12/31/96	PCB-10/96 Test Begun 11/96	27,387
7	Testing			3/30/97		
8	Final Report			6/30/97		
	TOTAL	**150,000**	**0**			**150,000**

PROGRAM TO MINIMIZE LOSSES IN MECHANICAL BATTERIES FOR ELECTRIC VEHICLES

Project Manager: **Avcon**
CS-AR95-01

During the quarter, the following tasks were completed successfully by Avcon:

- The test rig was fabricated and is full operational;
- The standard bearing has been manufactured; and
- The optimized bearing has also been designed and fabricated;

The completion of these tasks represents the completion of task 5, 6, 7 and 8 in the statement of work.

Avcon designed and built a robust, multipurpose test-bed for the purpose of testing the CALSTART magnetic bearing unit, which will be housed in a large concrete structure to provide protection during high-speed rotational testing. The analysis for an optimized bearing, designed to minimize eddy current losses, resulted in a design that required only minimal changes from the standard bearing. This design utilizes ferrous slot wedges between stator poles to eliminate the change in magnetic field that the rotor sees as it rotates under a slot. The optimized bearing, being a retrofit of the standard bearing, only requires the slot wedges to be added when it is ready for testing. The slot wedges are fabricated, so effectively the bearing is fabricated.

GOALS FOR NEXT QUARTER

Next quarter, the test rig will be used to test both the standard and the optimized bearing systems in-house. Avcon plans to assemble the standard bearing into the test rig fixture early in the next quarter, and begin testing. The ferrous slot wedges will be incorporated into the existing standard design with no need to disassemble the test rig or make a new bearing. The resultant flux change under the slot should be virtually eliminated, thereby eliminating the losses generated by these changes. These activities will be completed next quarter, completing tasks 9 and 10 of the contract agreement.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

PROGRAM TO MINIMIZE LOSSES IN MECHANICAL BATTERIES FOR ELECTRIC VEHICLES

Project Manager: ***Avcon***
CS-AR95-01

	MILESTONE	DARPA	MATCH	DUE DATE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	1 Develop Computer Model 2 Begin Rotordynamic Analysis 3 Develop Test Plan 4 Design Test Rig	37,706	37,706	9/30/96	9/30/96	37,706	37,706
2	Complete Rotordynamic Analysis	16,220	16,220	12/31/96	12/31/96	16,220	16,220
3	Complete Test Plan 5 Begin Fabrication of Test Rig	10,160	8,470	3/30/97	3/30/97		
4	Complete Fabrication of Test Rig	15,160	8,600	6/30/97	9/30/97	31,226	
5	6 Fabricate Standard Bearings 7 Design Optimized Bearings 8 Fabricate Optimized Bearings	12,182	23,618	9/30/97			
6	9 Test Standard Bearing	10,124	8,600	12/31/97			
7	10 Test Optimized Bearing 11 Iterate Computer Model	3,797	12,800	3/31/98			
8	Final Report	21,000	10,335	6/30/98			
		$126,349	**$126,349**			**85,152**	**53,926**

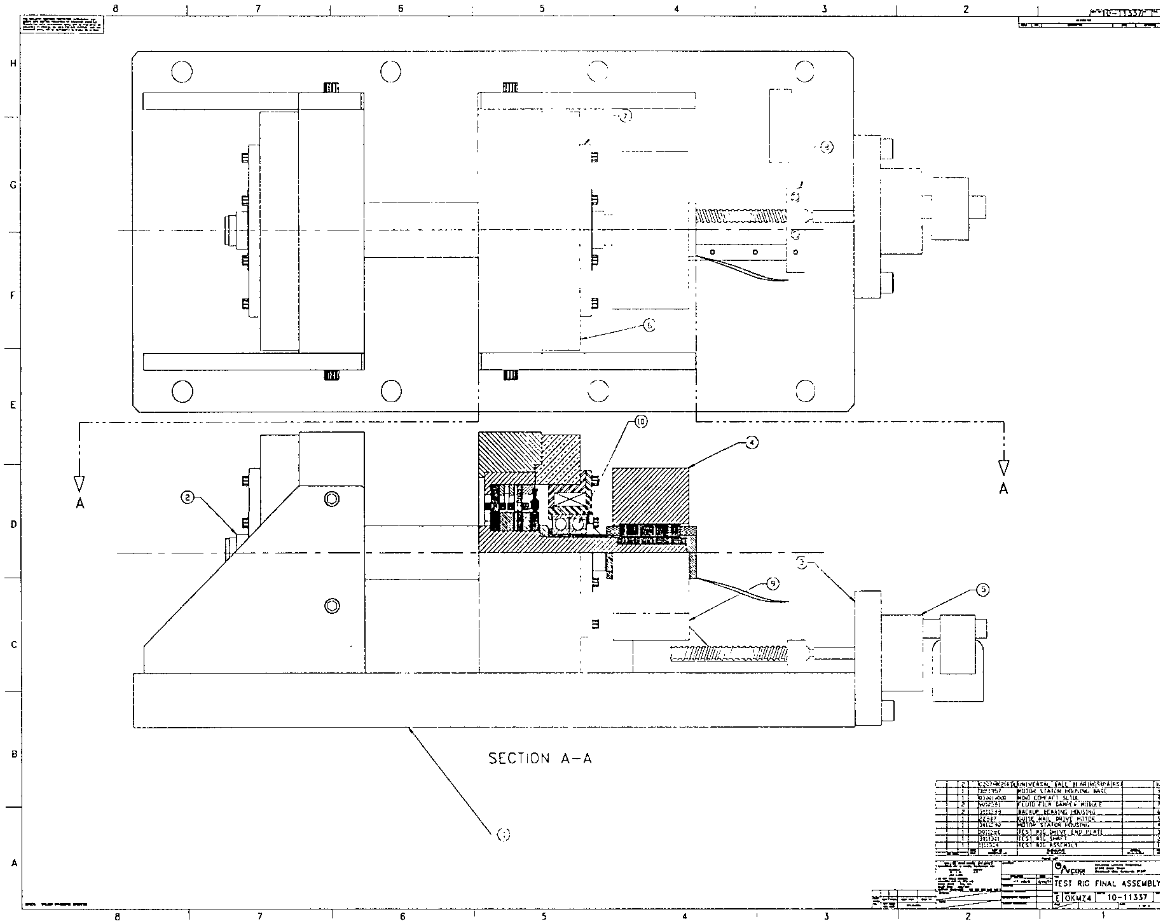


Figure 1. Test Rig System Assembly

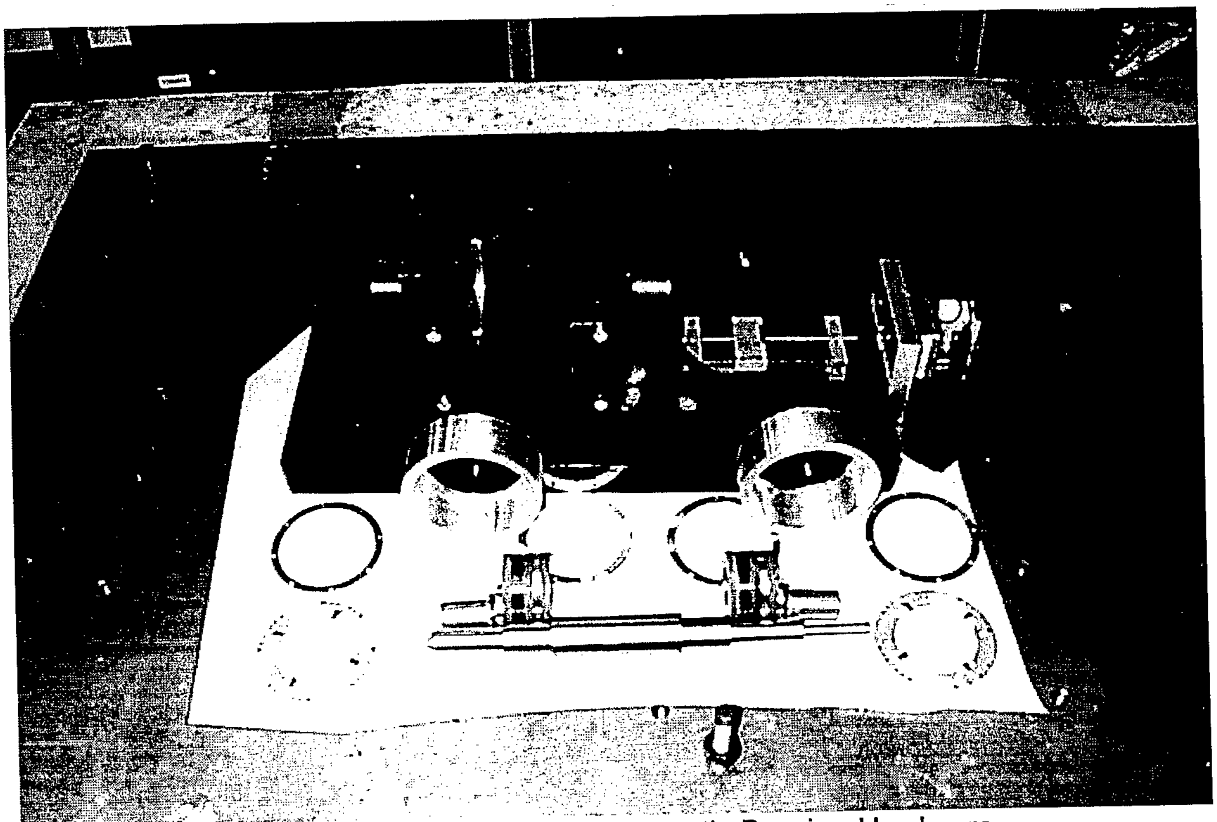


Figure 1. Test Rig and Magnetic Bearing Hardware

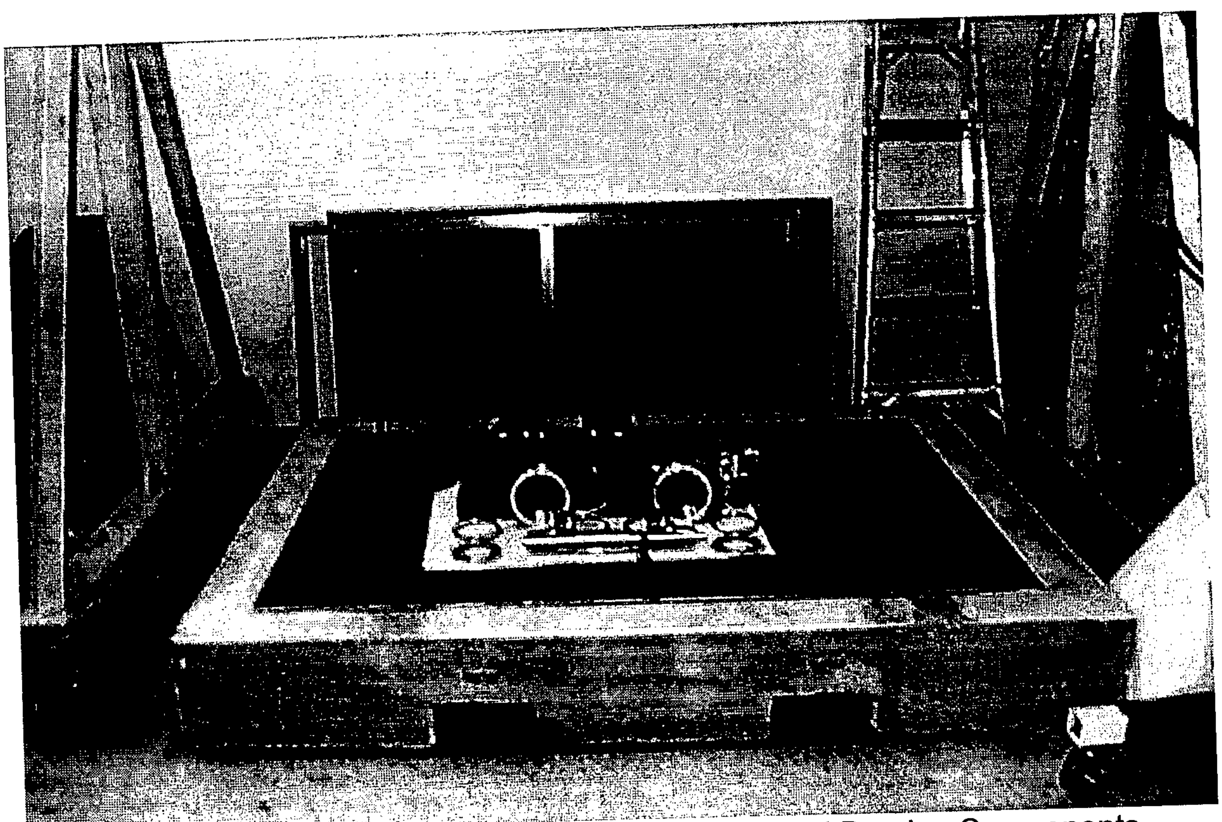


Figure 2. High Speed Test Base with Test rig and Bearing Components

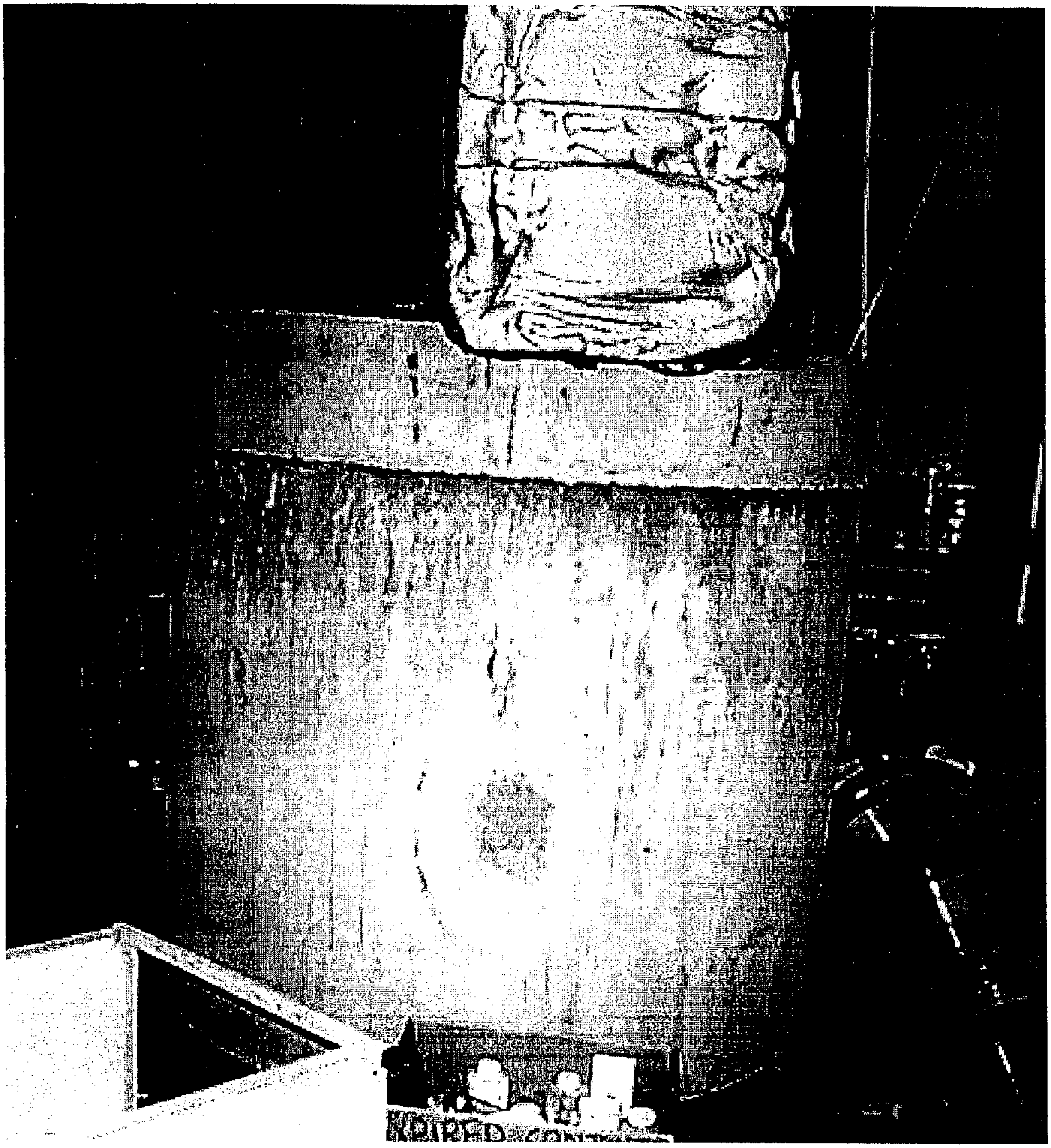


Figure 3. Test Rig Cover

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

FLYWHEEL LIFECYCLE TESTING

Project Manager: ***U.S. Flywheel Systems***
CS-AR95-02

During USFS's internal acceptance/check-out testing of the first two modules, it was determined that the magnetic bearings were not producing sufficient force for the flywheel to operate. Upon disassembly, tests on the bearings indicate that they were only producing one-fourth of their design specification force. Two re-worked bearings were received that did not meet design force specifications. All bearings were returned and re-worked bearings received and still, during this quarter, bearings received did not deliver the required force.

The first module was reassembled, however and moved to the spin pit to allow further completion of the control electronics and support equipment. This module is capable of spinning to ~18,000RPM before problems occur. The 2nd, 3rd, and 4th modules remain on hold pending resolution to the bearing problem.

Avcon continues to work on the bearings.

The DAS systems are installed and working. They will have a final calibration after the flywheel module is installed in the test chamber.

	MILESTONE	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Detail plan		900,000	1	7/7/96	7/16/96		
2	Fabricate flywheels	230,000	300,000	2	9/7/96	7/16/96	1,129,267	195,200
3	Design, prog. & fabricate DAS	90,000	140,000	3	9/7/96	12/2/96	318,126	171,057
4	Design/Install containment chambers	50,000	80,000	4	9/7/96	12/30/96		
5	Install modules/check system		60,000	5	10/7/96			
6	Cycle tests/statistical analysis	20,000	80,000	6	3/7/97			
7	Final report	10,000	40,000	7	6/7/97			
		400,000	**1,600,000**				**1,447,393**	**366,257**

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

COMPACT, RUGGED, LOW COST CIRCUIT BREAKERS FOR ELECTRIC AND HYBRID ELECTRIC VEHICLES

Project Manager: ***Coriolis Corporation***
CS-AR95-03

In this quarter, Coriolis and Potomac Electric Power Company completed the budget/milestones for the project. A final agreement was sent for signature near the end of the quarter. It is anticipated that the project agreement will be signed and the project will be active in the next quarter.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ALTURDYNE ROTARY ENGINE APU TRANSIT BUS DEMONSTRATION

Project Manager: ***APS Systems***
CS-AR95-04

During the quarter, APS finished fabrication and assembly of all of the drive systems for the bus. The Alturdyne Auxiliary Power Unit (APU) was subjected to substantial bench testing and found to be fully functional. APS integrated the unit into the bus for drive system testing. The APU performed beyond expectations and actually produced more power than originally anticipated.

However, during the testing, APS found that the APU was not delivering power to the batteries or motors. After extensive troubleshooting, the problem was revealed to rest with the GE Inverter. The inverter, contrary to GE's assurances, was unable to handle the high frequency power from the APU. APS elected to replace the inverter and has since been testing the electric drive and APU components separately. All of the components are performing to expectations. APS expects to re-integrate the APU with the electric drive system within the first few weeks of the next quarter, at which point the bus will be fully operational. (Note: As of the writing of this report - 10/28/97 -, the inverter had been replaced and the bus was fully operational).

CALSTART conducted several site visits during the quarter to insure that the project remained on schedule to the extent possible. Visits were made to APS in late July and mid-August. Another visit was scheduled pending the re-integration of the APU and electric drive system.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Alturdyne bus demonstration	65,000		1				
		65,000	**0**					**0**

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

SAFE ELECTROMECHANICAL BATTERIES FOR EVS

Project Manager: ***Rocketdyne***
CS-AR95-05

Rocketdyne submitted a Final Report (without invoice) to CALSTART on August 5, 1997. Following the burst test of the test disk, the project was scheduled to finish the installation, checkout, and the final data test of the EMB to the normal operating speed of 24,000 rpm. The available funding was not sufficient for the completion of these tasks and was used in preparation of the final report, which is included with this report. Rocketdyne had indicated to CALSTART that an additional $30,000 was needed to complete the program as originally scheduled. At a July 15, 1997 meeting with DARPA officials Mr. John Gully and Dr. Robert Rosenfeld, CALSTART's John Boesel explained this situation and conveyed Rocketdyne's request for additional funds. DARPA indicated that if there is a cost overrun, the participating organizations usually cover the additional costs with match funds. It seemed reasonable to DARPA to expect that a firm the size of Rocketdyne/Boeing should be able to cover such costs if it was truly committed to the product.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Containment ring design	50,000	552,000	1	12/31/96	12/31/96	552,000	63,472
2	Containment ring fabrication	75,000	77,000	2	3/30/97	3/30/97	77,000	97,463
3	Assembly checkout/test	100,000	77,000	3	6/30/97			12,221
4	Final report	34,500	77,000	4	9/30/96			
		259,500	**783,000**				**629,000**	**173,156**

ADVANCED HYBRID RECONNAISSANCE VEHICLES

Project Managers: ***AeroVironment and Rod Millen Special Vehicles***
CS-AR95-06A and B

Completion of the battery pack development and design of a two-speed transmission continue to be on hold. At the end of the quarter, AeroVironment began work to determine the availability of advanced battery modules that will allow testing to continue until the battery pack development task of this project is completed.

Two-speed transmission design work is on hold because of scheduling conflicts with the JTEV platform for other DARPA and Marine Corps requirements. The current schedule indicates that the JTEV will return from demonstration use at Caderock in mid-November 1997. At that time, the manual transmission will be installed. Rod Millen Specialty Vehicles (RMSV) will also work on installation of its advanced semi-active suspension at that time to limit the time that the JTEV is inoperable.

Because there has no progress on the above-referenced tasks, the scheduled deliverable reports will be delayed until the end of March 1998.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ADVANCED HYBRID RECONNAISSANCE VEHICLES

Project Managers: ***AeroVironment and Rod Millen Special Vehicles***
CS-AR95-06A and B

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
	RMSV CS-AR95-06A							
1	Initiate work	75,000		1	4/1/96	4/3/96		75,000
2	Suspension/ Differential Dev	60,287		2	4/30/96	6/30/96		13,881
3	Design review	60,287		3	6/30/96	6/30/96		59,688
4	Suspension design	60,287		4	9/30/96	9/30/96		75,894
5	Project Report			5	12/31/96	1/2/97		60,071
6	Algorithm dev. Final report	60,288		6	2/28/97			31,615
	TOTAL	**316,149**	**0**					**316,149**
	AeroVironment							
	CS-AR95-06B							
1	Battery Mgmt Final rpt Inverter repkg final Low Acoustic Trans rpt. Peripherals rpt	309,974	53,972	1	9/31/96	9/31/96	53,972	309,974
2	DC-DC converter Design	215,495	37,520	2	12/31/96	12/31/96	37,520	215,490
3	Final Report	58,385	0	3	3/30/97			
	TOTAL	**583,854**	**91,492**				**91,492**	**525,464**

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

PROPULSION SYSTEM FOR ADVANCED HYBRID RECONNAISSANCE VEHICLES

Project Manager: ***Rod Millen Special Vehicles and AeroVironment***
CS-AR96-09A and B

No significant milestones were accomplished during the quarter. Work continues on the development of the control system for the combined active damping and active ride height suspension system as well as fabrication of the active damper actuator and the active ride height actuator. However, availability of the JTEV platform continues to be an issue. Due to the JTEV's full schedule of demonstrations and testing this fall, an updated work schedule for the active damping and ride height suspension system project is proposed below. In this schedule, work which does not require the JTEV to be in the RMSV shop is given a higher priority and is scheduled earlier, while work which requires the JTEV, of for which having the JTEV accessible would be useful, is scheduled in 1998.

TASK	COMPLETION DATE	% COMPLETE
Design of complete suspension control system	September 1997	100%
Detail Design and Fabrication of Suspension System Hardware	December 1997	60%
Testing	March 1998	20%
Test Platform Support	March 1998	0%
Analysis and Reporting	Quarterly/March 1998	30%

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

PROPULSION SYSTEM FOR ADVANCED HYBRID RECONNAISSANCE VEHICLES

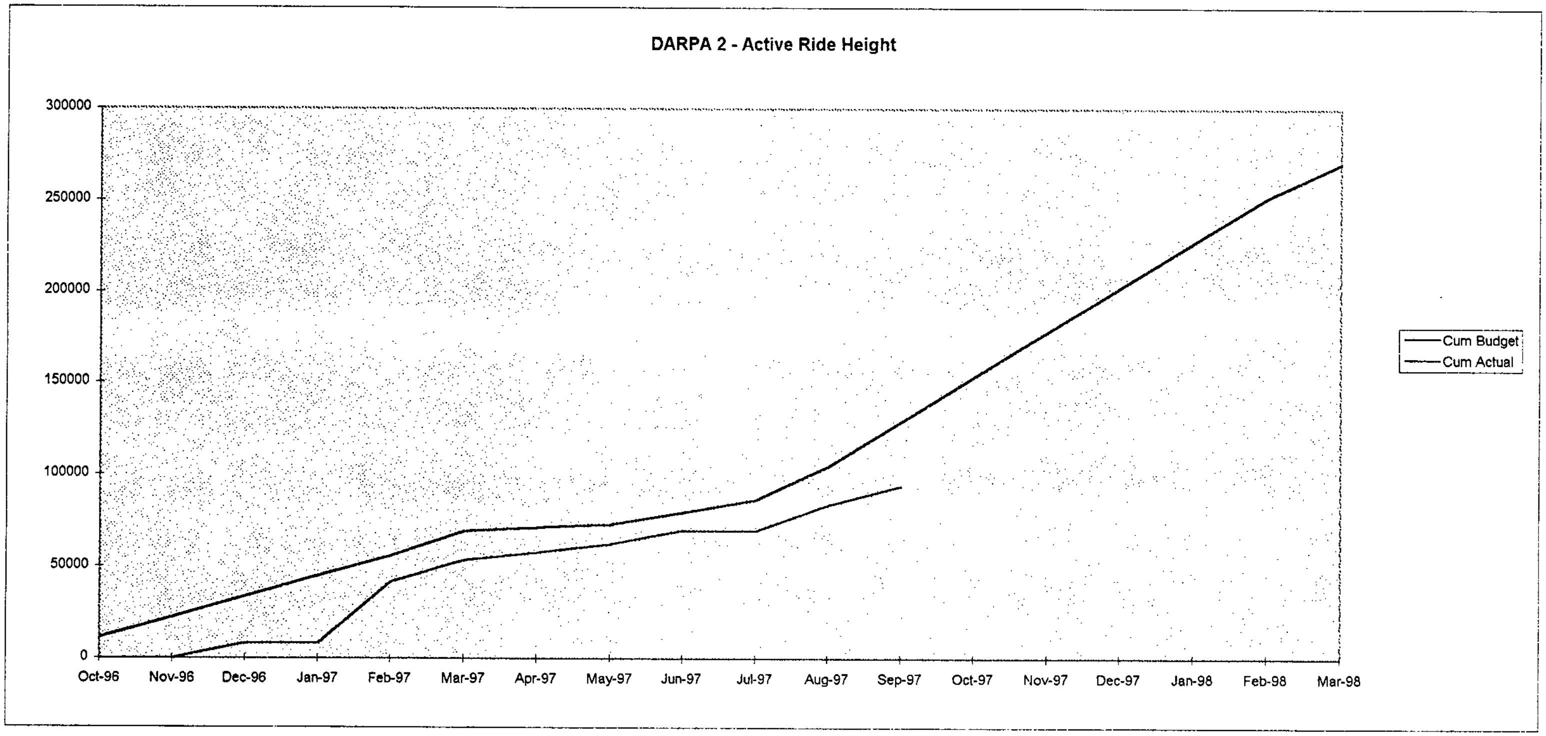
Project Manager: ***Rod Millen Special Vehicles and AeroVironment***
CS-AR96-09A and B

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
	AeroVironment CS-AR96-09A							
1	Initiate Work	69,282		0	12/31/96	12/31/96		**68,424**
2	Pack Mechanical Design Report	72,727		1	3/30/97			
3	Battery Progress Report	92,727		2	6/30/97			
4	2 Speed Trans report	74,066		3	9/30/97			
7	Final Report	50,910		4	12/31/97			
		359,712	**0**					**68,424**
	ROD MILLEN CS-AR96-09B							
1	Initiate work	38,614		1	9/30/96	9/30/96		38,614
2	Test platform support	38,615		2	12/31/96	12/31/96		8,361
3	ADC fabrication	38,615		3	3/30/97		6,000	42,962
4	ADC testing	38,615	10,000	4	6/30/97			18,505
5	ADC integrated JTEV	38,615	10,000	5	9/30/97			
6	Algorithms refined	38,615	10,000	6	12/31/97			
7	Test complete/Final report	38,615	6,000	7	3/30/98			
		270,304	**36,000**				**6,000**	**108,442**

DARPA/CALSTART-Active Ride Height & Damping Control
Budget vs. Actual by month

	Oct-96	Nov-96	Dec-96	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97
Budget	11193	11193	11193	11193	11193	13162	1969	1969	6551	6551
Actual			8361	0	32923	11985	4122	4817	7620	-157
	Oct-96	Nov-96	Dec-96	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97
Cum Budget	11193	22387	33580	44773	55967	69129	71097	73066	79617	86168
Cum Actual	0	0	8361	8361	41284	53269	57391	62208	69828	69671

	Aug-97	Sep-97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Total
Budget	18274	24520	24520	24520	24520	24520	24520	18740	270303
Actual	13910	10401							
	Aug-97	Sep-97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	
Cum Budget	104442	128962	153482	178003	202523	227043	251564	270303	
Cum Actual	83581	93982							



Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ROTARY ENGINE AUXILIARY POWER UNIT DEMONSTRATION

Project Manager: ***Aerobotics, Inc. a division of Moller International***
CS-AR95-07

Moller reports that Bolder Battery Incorporated has now delayed the delivery of promised batteries from September, 1997 to February 1998. This arrival date is significantly later than originally anticipated. Other batteries are currently being monitored, regularly charged, and their voltage well maintained.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Complete design	40,000	108,320	1	3/6/96	5/31/96	112,793	40,000
2	Order batteries/tooling	57,855		2	3/30/96	5/31/96	15,125	53,162
3	Finish block fabrication	25,000	46,500	3	5/15/96	12/30/96	6,188	38,490
4	Receive/Evaluate Geo Metro	16,495		4	8/16/96	8/25/96	23,531	46,201
5	Drivetrain/Engine Installation	37,500	37,500	5	10/4/96	12/96	30,000	22,489
6	Vehicle testing	23,492	15,000	6	12/15/96	3/30/97		
7	Final report	32,013	10,000	7	2/4/97			
		232,355	**217,320**				**187,6387**	**200,342**

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

QUICK CHARGING SYSTEM WITH FLYWHEEL ENERGY STORAGE

Project Manager: ***Trinity Flywheel Battery***
CS-AR96-01

During this quarter, one problem arose when Trinity Flywheel Battery (Trinity) learned of the announced closure by Pacific Gas & Electric Corporation (PG&E) of the Modular Generation and Test Facility (MGTF).

PG&E was going to work with Trinity to complete the test of the rapid charger system (RCS) at their site. With that site closed, Trinity must now look for an alternate suitable location. Trinity determined that specifications depend significantly on site and operational requirements of the charging station. Trinity is having the RCS concurrently engineered, mitigating its dependence on site and operational requirements to the extent possible.

The line interface unit (LIU) is being developed by Trace Engineering, while the flywheel interface unit (FIU) is being built by SL Montevideo Technology Inc. Trace and Montevideo developed the LIU and FIU to allow a variety of operating modes including pulsed and non-pulsed charging and power flow balancing between the flywheel and the line.

Trinity has begun drive and control testing of the flywheel motor/generator (FMG). The team has achieved high speed operation (39,000 RPM) and high power discharge (~50 kW). In addition, Trinity has demonstrated system controls, safety monitoring and alarms.

Trinity has also completed an internal review and established and submitted a preliminary test plan. The team has reviewed the FIU, LIU and FMG. Trinity has completed design of the system, major subsystem and components. They have created detailed drawings and released most for fabrication.

CALSTART continued to monitor Trinity's progress throughout the quarter and met with representatives from Trinity to discuss the project and make sure it was remaining on schedule. Trinity presented information to the CALSTART technical advisory committee on a related flywheel project and the technology in general.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

QUICK CHARGING SYSTEM WITH FLYWHEEL ENERGY STORAGE

Project Manager: ***Trinity Flywheel Battery***
CS-AR96-01

ACTIVITIES PLANNED FOR NEXT QUARTER

Trinity plans to develop the RCS specification once a new test site is firmly defined by PG&E. It is possible that PG&E may be able to lease its test facility for the purpose of allowing Trinity to complete its testing related to this program. The system performance and specification report is also scheduled for completion next quarter. In addition, Trinity will demonstrate bi-directional power flow management consistent with the LIU interface requirements. The Intermediate design review also will be completed next quarter, as will the test program review and design review. The engineering drawings will be completed next quarter and the documentation will be assembled for the design review. Trinity plans to complete the assembly drawings that are not critical to fabrication and component delivery next quarter as well. Manufacturing and testing the system is contingent upon completion of the engineering design, which should be completed by the end of next quarter.

DEVIATIONS TO PLAN

Trinity continues to recover schedule and remain under budget. The progress is expected to continue next quarter and the project should be back on schedule by the end of the quarter.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
0	Initiate work	64,085	7,200		1/30/97	1/30/97	7,200	64,085
1	Flywheel/Interface/FESS/ LIU Specifications	119,298	45,600	1	3/30/97	3/30/97	45,600	
2	Design review/initial testing	116,791	88,400	2	6/30/97	6/30/97	48,211	
3	Manufacture/Phase 1 testing	37,895	320,146	3	9/30/97			
4	Installation drawings/program review	137,618	28,800	4	12/31/97			
5	Integration and initial check-out		33,900	5	3/30/98			
6	Final report	77,401	32,550	6	6/30/98			
	TOTALS	**553,088**	**556,596**				**101,011**	**64,085**

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ENVIRONMENTAL CONTROL SYSTEM FOR ELECTRIC AND HYBRID VEHICLES

Project Manager: ***Glacier Bay***
CS-AR96-02A

The project is currently four weeks behind schedule. Design and integration of the heating option should have been completed, but will not be done until early November. Bench testing of the heating option will also be performed by Glacier Bay in early November.

Testing of the air conditioning unit was performed in Florida (see CS-AR96-02B, below).

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
	Glacier Bay and Evermont CS-AR96-02 AC DEV/TEST							
1	Preliminary Design	20,000			10/25/96	10/25/96		20,000
2	Design of Major Components	34,573	44,113	1	12/31/96	12/31/96	44,113	34,573
3	Production of Major Components. Prototype Bench Testing and Production Drawings	55,000	60,000	2	3/31/97		60,000	53,076
3	Final System Assembly Testing of ACS on PIVCO in Calif and Evermont Vehicle in Florida and Georgia	50,000	45,000	3	6/30/97		30,480	
4	Design, Production, Performance Testing of Fossil Fueled Option	17,000	21,000	4	9/30/97		42,511	
5	Installation and testing of fossil fueled option	35,000	8,000	5	12/31/97			
6	Final report	23,427	11,887	6	3/31/98			
	TOTAL	**150,000**	**140,000**				**177,104**	**107,649**

COOPERATIVE TESTING

Project Manager: ***Glacier Bay*** *with* ***EVermont***

Due to problems with the test vehicle, testing of the air conditioning unit in Florida was limited to one day. The testing that was completed showed that the Glacier Bay system gave performance equal to that of the factory system operating at freeway speeds and that the Glacier Bay system actually outperformed the factory system in "stop and go" traffic conditions.

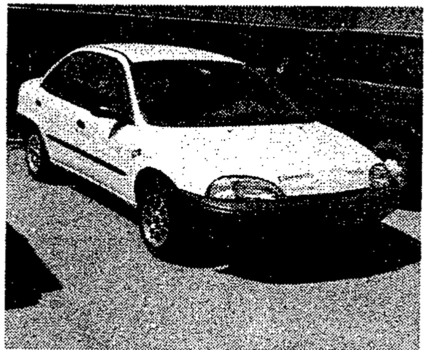
The air conditioning unit was installed by Glacier Bay on the EVermont Solectria at Glacier Bay's facilities in Northern California. Following installation and initial testing, the vehicle was shipped to Florida for testing by the Florida Solar Power Research Institute. Upon arrival in Florida, the Solectria was found to have an irreversibly discharged battery pack. This necessitated that Glacier Bay personnel go to Florida to remove the air conditioning system in order for the battery pack to be replaced. Following replacement of the battery pack, a single day of testing was completed. However, problems with the vehicle's on-board charger resulted in no additional test days. The Glacier Bay system was removed from the vehicle and shipped back to Northern California.

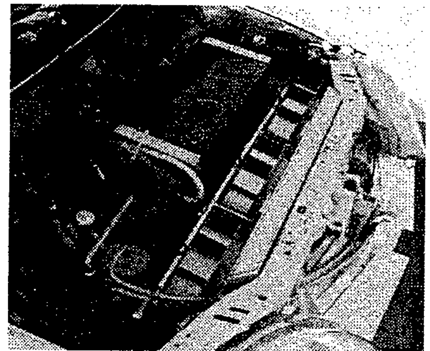
A more detailed review of the data gathered by Florida Solar Power Research Institute will be included in next quarter's report. The data is currently being complied and analyzed. Initial testing of the vehicle at Glacier Bay's Northern California facilities indicated that the vent air temperature dropped from 94.2 degrees Fahrenheit to 50.2 degrees Fahrenheit in 127 seconds. Elapsed time temperature readings from this test are detailed below:

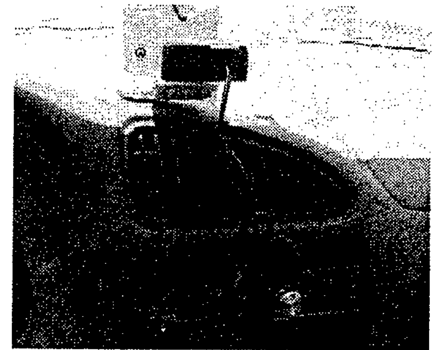
- Starting Temperature: 94.2 degrees
- 14 seconds elapsed time: 80.3 degrees
- 28 seconds elapsed time: 70.0 degrees
- 61 seconds elapsed time: 60.0 degrees
- 127 seconds elapsed time: 50.2 degrees

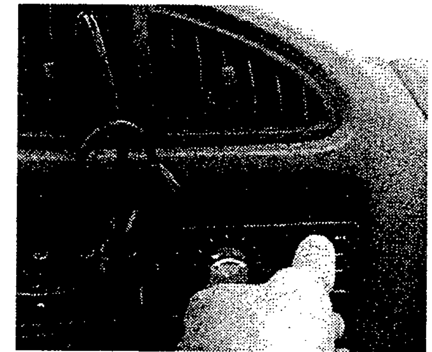
Glacier Bay plans to work with EVermont during the next quarter to develop a detailed testing protocol for the heating option.

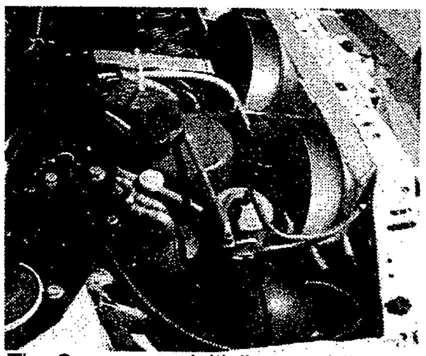
Attachment 'T-1'


Completed EVermont / Geo Metro in full sun-soak prior to the start of the test.

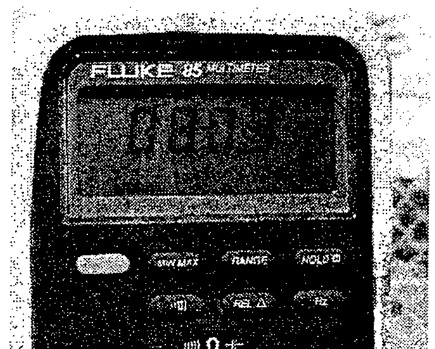

Open hood showing installed equipment. Compressor, Receiver and Condenser Blowers are clearly visible.


Fluke 86 digital temperature probe is installed to monitor and visually indicate the driver's vent air temperature.


The temperature control of the Glacier Bay ECS is set to full power and the unit is turned on.


The Compressor initializes and the Condenser Blowers begin to spin.

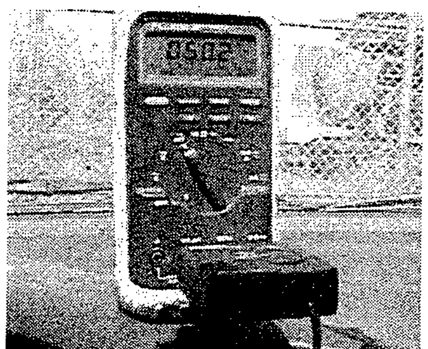

A quick check of the temperature display shows the starting temperature to be 94.2 degrees F.



Total elapsed time: 14 seconds.
The vent air temperature has fallen to 80.3 degrees F.

Total elapsed time: 28 seconds.
The vent air temperature has fallen to 70.0 degrees F.

Total elapsed time: 61 seconds.
The vent air temperature has fallen to 60.0 degrees F.


Total elapsed time: 127 seconds.
The vent air temperature has fallen to 50.2 degrees F.

Glacier Bay, Inc.
Environmental Control System for Electric & Hybrid Vehicles (ECS)

This series of still images is taken from a videotaped test of the Glacier Bay ECS in San Mateo California on 8/5/97, the day before the car was shipped to the Florida Solar Power Research Institute where it underwent further testing.

E/HEV MANUFACTURABILITY ASSISTANCE PROGRAM

Project Manager: CALSTART
CS-AR96-04

CALSTART proposed that this project be replaced with a heavy duty vehicle industry analysis. CALSTART is awaiting DARPA's decision on the proposed replacement. No work on the E/HEV Manufacturability Assistance Program was performed during this quarter.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HYBRID-ELECTRIC PROTOTYPE TRUCK (HEPT) PROJECT

Project Manager: ***ISE Research***
CS-AR96-05

ISE Research (ISER) continued to make progress on the truck through the quarter. They accomplished several of the tasks set forth in the contract.

ISE began work on a supplementary $350,000 contract from the California Air Resources Board (CARB), which is funding a second prototype HEPT truck. ISER completed the auxiliary power unit (APU) for the DARPA funded truck (truck 1) and integrated a 75 kW Fisher alternator-generator with the General Motors V6 engine installed last quarter. ISER and subcontractor United Defense, LP (UDLP) completed the design of the advanced AC motor which will be used in both HEPT vehicles.

ISER also ordered all the major components for the AC motor in the vehicles. In addition, ISER and Siemens initiated a collaborative R&D project to develop a low-cost modular motor controller concept based on Siemens' line of industrial motor controllers. An in-depth trade study addressing design and installation of electrically driven accessories was performed as well.

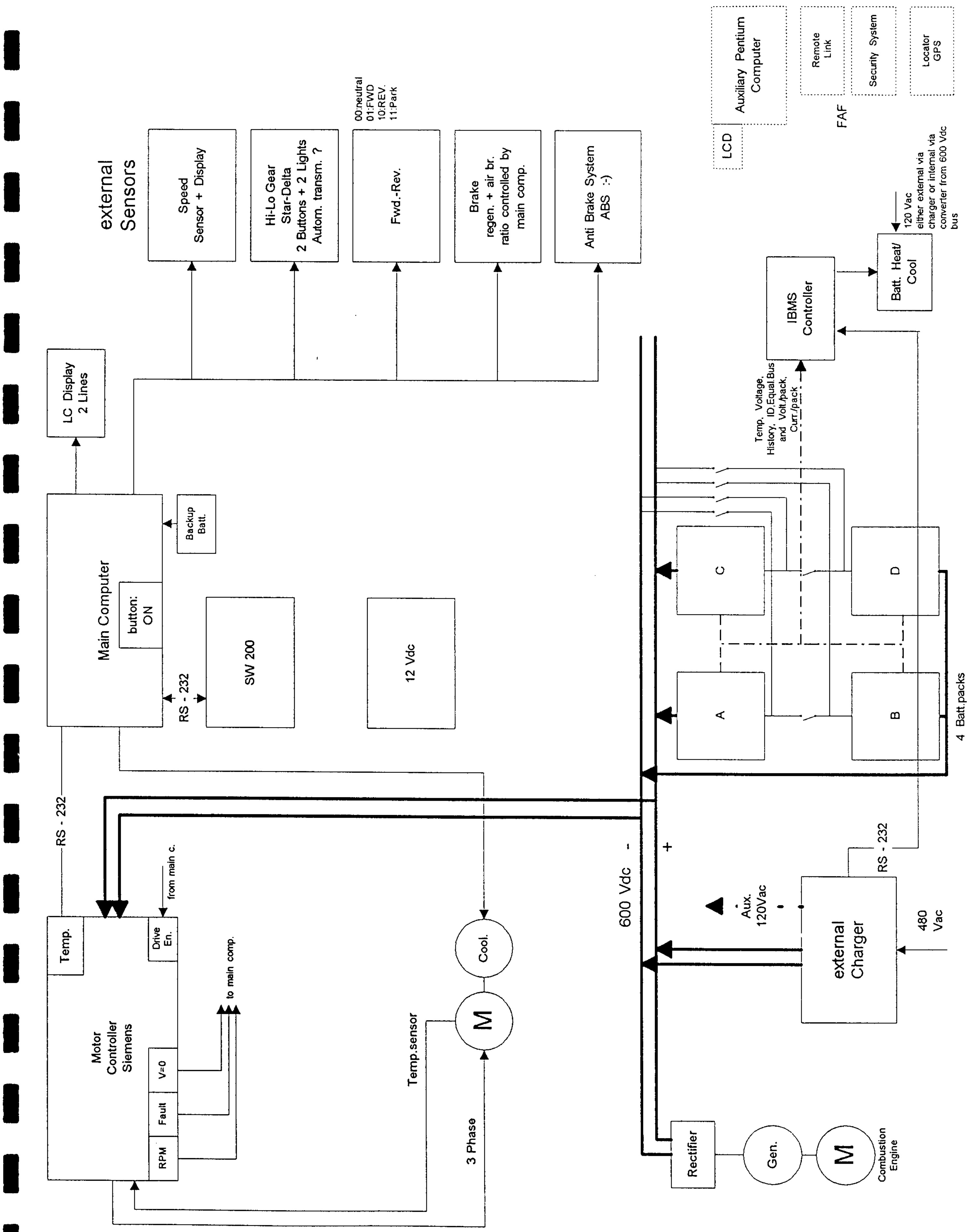
A major HEPT status meeting was held with the Kenworth Truck Company at Kenworth's Seattle-area facilities. ISER also completed its first heavy-duty electric vehicle, an airport tow tractor for United Airlines, verifying certain key aspects of the high-voltage electric energy storage subsystem. ISER also completed the Preliminary Design Review for its "Hybrid-Electric Tow Tractor" contract with the U.S. Air Force. ISER updated its corporate business plan and began negotiating with Florida-based Corporate Builders, LP for assistance in securing investor financing for commercialization of all of its HEPT technologies.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HYBRID-ELECTRIC PROTOTYPE TRUCK (HEPT) PROJECT

Project Manager: ***ISE Research***
CS-AR96-05

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Drive system design approved. System controller design compete	30,000	96,700	1	1/10/97	1/10/97	95,443	30,000
2	System controller modules design. APU/genset integrated/tested	35,000	100,000	2	4/10/97	3/30/97	162,333	35,000
3	Vehicle integration plan complete	35,000	75,000	3	7/10/97	3/30/97		20,000
4	Major components integrated	30,000	50,000	4	10/10/97			15,000
5	Vehicle fully integrated/testing initiated	30,000	75,000	5	1/10/98			
6	Phase 1 Operational testing complete	30,000	50,000	6	4/10/98			
7	Commercialization plan initiated	30,000	25,000	7	7/10/98			
8	Phase 2 testing complete/Business plan approved	5,000	25,000	8	10/10/98			
9	Final report	25,000		9	1/10/99			
		250,000	**496,700**				**257,776**	**100,000**



external Sensors
Speed Sensor + Display
Hi-Lo Gear Star-Delta 2 Buttons + 2 Lights Autom. transm. ?
00:neutral
01:FWD
10:REV.
11:Park
Fwd.-Rev.
Brake regen. + air br. ratio controlled by main comp.
Anti Brake System ABS :-)
LCD
Auxiliary Pentium Computer
Remote Link
Security System
Locator GPS
FAF
LC Display 2 Lines
Main Computer
button: ON
Backup Batt.
RS - 232
SW 200
12 Vdc
IBMS Controller
Batt. Heat/ Cool
120 Vac either external via charger or internal via converter from 600 Vdc bus
Temp, Voltage, History, ID,Equal.Bus and Volt./pack, Curr./pack
C
D
A
B
4 Batt.packs
RS - 232
600 Vdc
-
+
Aux. 120Vac
external Charger
480 Vac
RS - 232
Temp.
Drive En.
from main c.
Motor Controller Siemens
V=0
Fault
RPM
to main comp.
Cool.
M
Temp.sensor
3 Phase
Rectifier
Gen.
M
Combustion Engine

FIGURE 1

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ELECTRIC VEHICLE LONG RANGE EXTENDING GENERATOR

Project Manager: ***AC Propulsion***
CS-AR96-06

AC Propulsion is nearing completion of this project and anticipates presenting their final report in the next quarter.

During this quarter, AC Propulsion completed the design work on the alternator, including changes to the housing, end-plates and bearings to accommodate the belt-drive configuration. Other completed design work includes the control system design and packaging layout, and a belt-drive using a 30mm-wide, 8mm-pitch drive-belt and commercially available drive-belt pulleys.

The shaft-mounted fan design was successfully tested for air flow and efficiency. The control strategy was simplified by allowing alternator output to be directly controlled by alternator speed, eliminating switched capacitors. The steep slope of the alternator output/speed curve allows full control of output over a very narrow speed range so output regulation can be achieved with closed-loop control of operating speed.

Construction of the alternator and control system prototypes was completed in August. In September, the prototype charging system successfully tested in a series of dynomometer tests of output, efficiency, operating temperature over-voltage and over-current protections. The target output of 20 kW was achieved with efficiency at 90-91%.

The AC-Propulsion alternator – Moller engine power system has been mounted to a test stand and instrumented for monitoring and collection of operational data. The engine control system has proven to be incompatible with the alternator control system due to the rapid transients required for automatic alternator output control. The Moller fuel system could not track rapid throttle excursions so manual control had to be used for all tests of the charging system.

At the specified engine speed of 5,000 rpm, maximum electrical output of 14.5 kW was produced at wide-open-throttle. Discussions with Moller indicated that higher output could be achieved at higher rpm, although rotor tip seal life deteriorates as speed increases. At maximum output, engine temperature control required a large auxiliary air blower to augment the flow of the integral engine cooling fan.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ELECTRIC VEHICLE LONG RANGE EXTENDING GENERATOR

*Project Manager: **AC Propulsion***
CS-AR96-06

Fuel consumption at maximum output was 0.8kg/kWh, which is high for this type of application. Adjustment to the throttle control linkage provided only limited authority over air-fuel ratio. Output from the O2 sensor indicated that the fuel mixture was near stoichiometry. Exhaust pressure was 1.5 psi.

AC Propulsion is looking forward to the DARPA review on November 4, 1997 in Sacramento, California as they bring this project to a close.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Design study complete	51,000	57,000	1	1/10/97	1/10/97	52,211	51,000
2	Prototype charging system constructed	72,000	53,000	2	4/10/97	3/30/97	46,600	72,000
3	Moller engine delivered	22,000	25,000	3	7/10/97	8/30/97		30,000
4	Integration complete	8,000	11,000	4	10/10/97	9/30/97		
5	Testing complete	8,000	15,000	5	1/10/98			
6	Final report	9,000	9,000	6	4/10/98			
	TOTALS	**170,000**	**170,000**				**98,811**	**153,000**

ENGINEERING IMPROVEMENTS FOR PURPOSE-BUILT EV

Project Manager: ***PIVCO***
CS-AR96-07

There is no change from last quarter. The contract is not yet in place with PIVCO. A new statement of work and milestone chart needs to be submitted prior to finalizing contract.

DISTRIBUTED ENERGY MANAGEMENT SYSTEM (DEMS) DEVELOPMENT AND DEMONSTRATION

Project Manager: ***Hughes Technical Services Center***
CS-AR96-08 and CS-AR94-04

Complete installation and testing of the multi-controller (CC137) system on three Greater Richmond Transit buses is suspended indefinitely because of a brake safety violation on the Blue Bird buses. Blue Bird is redesigning the brake system and expects the buses to be operational by January 1998. Installation and testing work will resume at that time.

Conversion of the CC200 DEMS battery module to a 68HC705JP7 micro-controller, which is lower in cost than the 68HC05C8, has been completed. However, testing of the DEMS battery module communications software has revealed a software throughput problem with the micro-controller. A new micro-controller with a SCI bus has been incorporated into the DEMS battery module and board layout is in progress. However, these changes have resulted in an estimated 10 week delay in completion of the DEMS and subsequent testing. Also, design changes that resulted in changes to the competitive bid process for fabrication of the CC200 DEMS central controller have resulted in additional delays.

Current and past delays in the project result in a total delay of 16 weeks from the original expected completion date. Hughes does not anticipate being able to make up this delay.

During the next quarter, Hughes expects to:

- Complete DEMS battery module redesign, fabrication and test of prototype unit;
- Complete CC200 DEMS battery module communication software design and test;
- Complete DEMS battery module control software and test;
- Complete DEMS central controller and battery module communication software test system;
- Fabricate DEMS CC200 central controllers;
- Fabricate prototype DEMS modules; and
- Begin DEMS central controller control algorithm software design.

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

DISTRIBUTED ENERGY MANAGEMENT SYSTEM (DEMS) DEVELOPMENT AND DEMONSTRATION

*Project Manager: **Hughes Technical Services Center***
CS-AR96-08 and CS-AR94-04

	MILESTONES CS-AR94-04	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	Requirements defined. Concept for controller hardware defined	30,000	50,000	1	6/30/96	6/30/96	281,022	
2	Software defined and programmed.	30,000	50,000	2	9/30/96	9/30/96	150,979	
3	Design/Implementation of multiple pack system controller	70,000	370,000	3	12/31/96	12/31/96	15,474	
4	Software installed on 25kW Inductive Opportunity Charge system.	50,000	15,000	4	3/30/97	3/30/97	146,051	
5	Bluebird buses equipped Field data acquired DEMS upgrade concept complete/controller built	70,000		5	6/30/97			
		250,000	**485,000**				**593,526**	**0**

	MILESTONES CS-AR96-08	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
5	Bluebird buses equipped Field data acquired DEMS upgrade concept complete/controller built	200,000	108,000	5	6/30/97			
6	Final report.	50,000	15,000	6	9/30/97			
		250,000	**123,000**					

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ASSESSMENT OF ADVANCED ENGINE TECHNOLOGIES FOR UAV AND HEV APPLICATIONS

*Project Manager: **FEV Engine Technology***
CS-AR97A-02

During this quarter, FEV continued the assessment of advanced engine technologies (highly boosted conventional 2- and 4-stroke engines) for unmanned air vehicle (UAV) and hybrid electric vehicle (HEV) applications. FEV also began the process of assessing the Engine Corporation of America (ECA) Thermal Electric Compound Engine (TECE) with respect to the thermodynamic and mechanical claims.

Testing of a 4-cylinder, 4-stroke, 1.9 liter automotive diesel engine with special variable geometry turbocharger indicates the power is currently limited by 2-valve design, turbocharger performance and the fuel injection system. Additional power is possible with a 4-valve cylinder head design. The current weight of 220 pounds could be significantly reduced with an aluminum block, air cooling and other aircraft-type features. Fuel consumption was 0.37 pounds per horsepower hour at 2,500 revolutions per minute (rpm) and two-thirds power.

Testing of a 1-cylinder, 4-valve, uniflow-scavenged 2-stroke engine for UAV applications is underway. Initial tests demonstrate that greater than 160 horsepower would be available from a 1.9 liter engine. The engine is currently limited to 3,000 rpm due to the fuel injection system, but higher power is possible with an improved fuel injection system. Fuel consumption cannot be directly compared due to much higher relative friction for a 1-cylinder engine compared to multi-cylinder engines. However, generally the fuel consumption will be higher compared to the 4-stroke engine at an equal power level.

Thermodynamic assessment of the TECE engine was done with the FEV cycle simulation tool EPOS. The assessment was performed in two steps:

1. An initial optimization of the gas exchange process was conducted.
2. High combustion pressure cycle simulations were conducted.

Defense Advanced Research Projects Agency
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Quarterly Report
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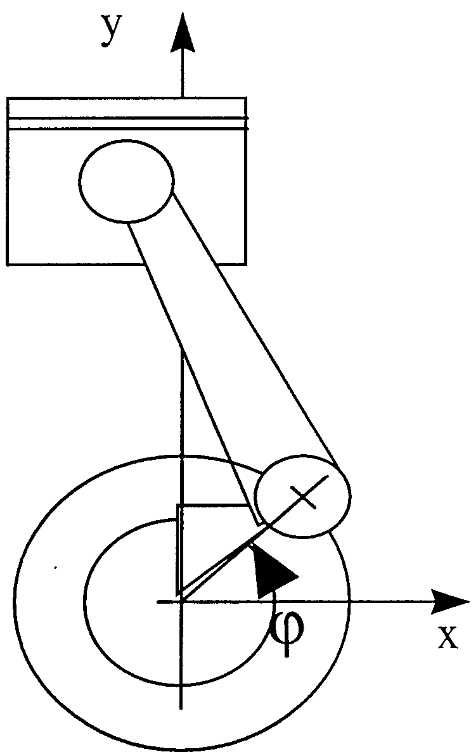
ASSESSMENT OF ADVANCED ENGINE TECHNOLOGIES FOR UAV AND HEV APPLICATIONS

*Project Manager: **FEV Engine Technology***
CS-AR97A-02

Preliminary scavenging and combustion analyses suggest that thermal efficiencies of 50 percent may be possible from 1.0 liter displacement, depending upon actual volumetric efficiency, turbocharger efficiency and friction levels of the TECE multi-cylinder engine. Analyses also suggest that the practical limit of cylinder firing pressure, with respect to increasing engine efficiency, may be lower than ECA originally estimated. The ability of piston and connecting rod design to prevent high side forces and high friction appears promising but needs to be evaluated further, and several questions remain regarding a fuel injection system for use with such high cylinder pressures found in the TECE.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	DATE COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	TECE Thermo/Mech Assessment	50,000	50,000	1	9/30/97			
2	2/4 Stroke Concept Assessment	250,000	470,000	2	12/30/97			
3	2.4 Stroke Demo. Final Report	700,000	480,000	3	3/30/98			
	TOTAL	**1,000,000**	**1,000,000**					

Figure 1.1.2 - 1
Definition of Crank Angle and Valve Timing



Valve timing according to these definitions is:

Geometrical TDC	°CA	17.4
Geometrical BDC	°CA	212.9
Intake slots:		
Intake slot opens	°CA	172
Intake slot closes	°CA	249
Exhaust slots:		
Exhaust slot opens	°CA	165
Exhaust slot closes	°CA	249

FEV Engine Technology

Figure 1.1.2 - 2

Comparison of TECE to Conventional Engine

Cylinder Volume versus Crankangle

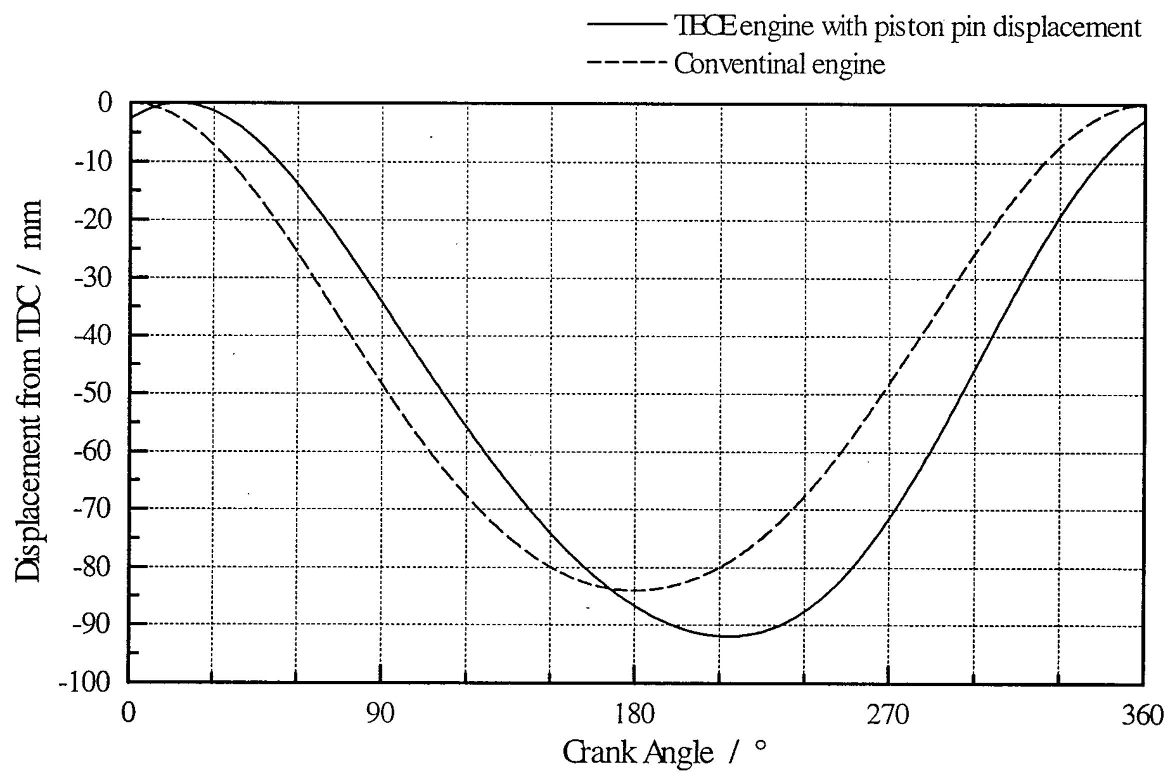


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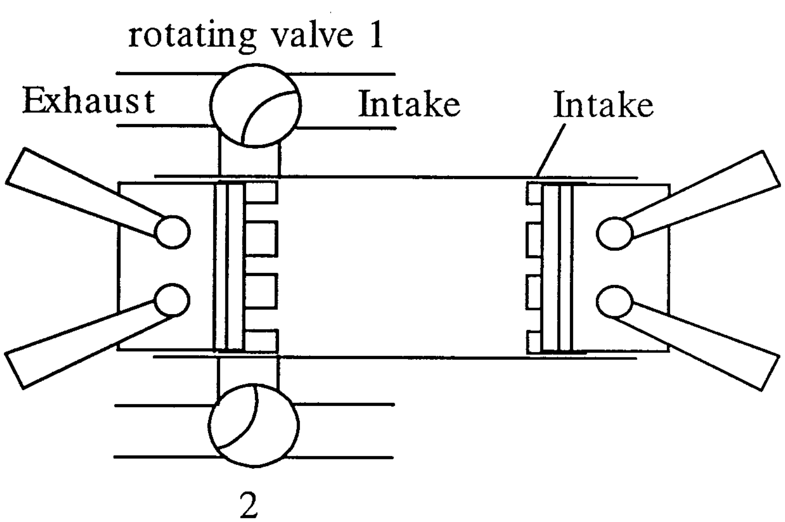
Figure 1.1.2 - 3
Layout of the TECE and Timing of the Rotary Valve



The basic timing for the switches is:

First exhaust slot closes	**174°CA**
First exhaust slot opens as intake	**184°CA**
Second exhaust slot closes	**224°CA**
Second exhaust slot opens as intake	**234°CA**

FEV Engine Technology

Figure 1.1.2 - 4
In-cylinder Pressure and Mass Flow versus Crank Angle for TECE

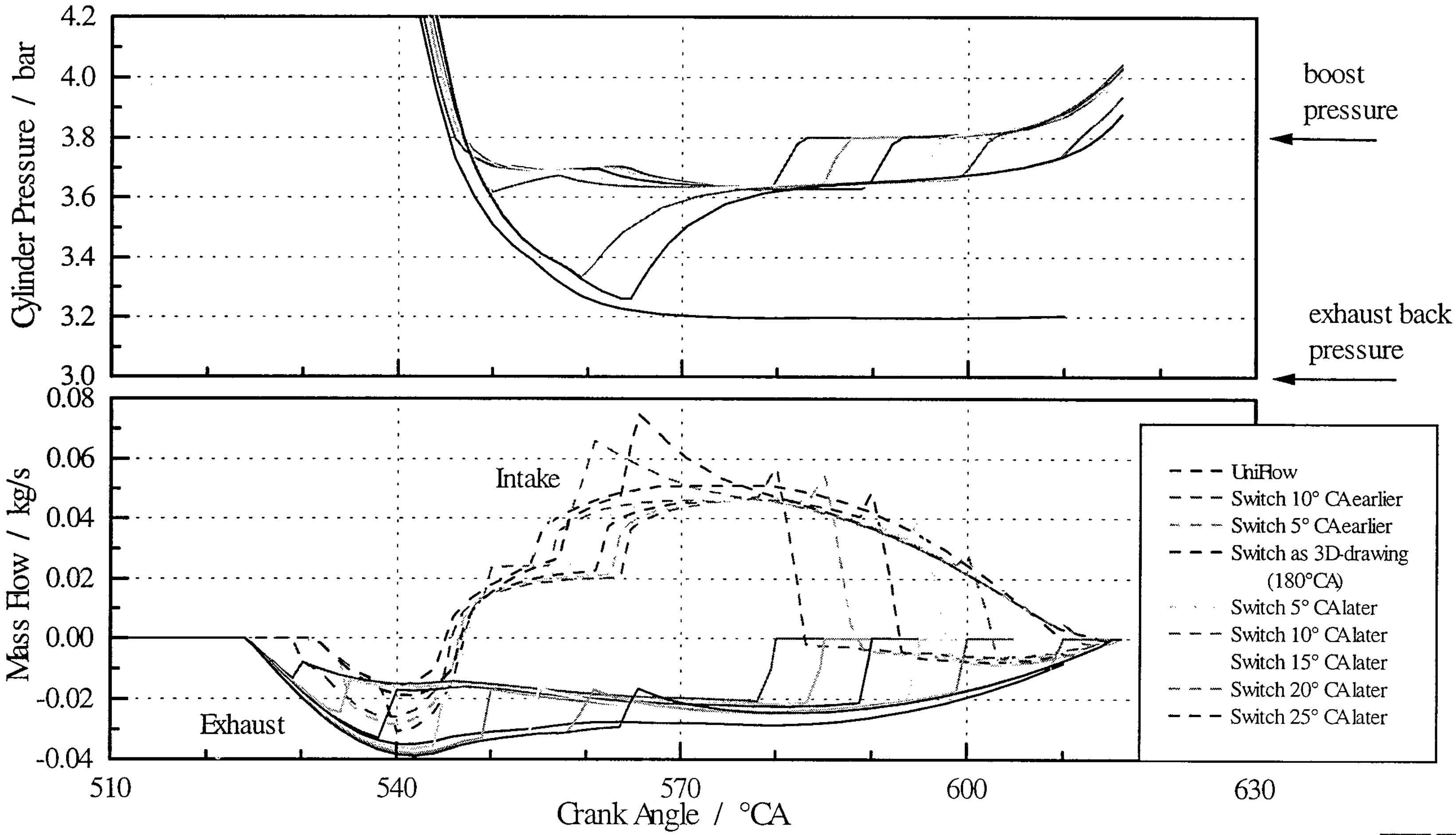


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Figure 1.1.2 - 5
Effect on Overall Volumetric Efficiency through Variation of Rotary Valve Timing

Switch of exhaust slots to intake: Difference between switches is 50°CA=constant (value taken from 3-D-drawing)

Assumptions:

Ideal switch (no time delay between EVC and IVO)

Minimum valve area is slot area; open area of rotational valve always is larger than slot area)

BMEP=??
mBR/Asp=65 mg

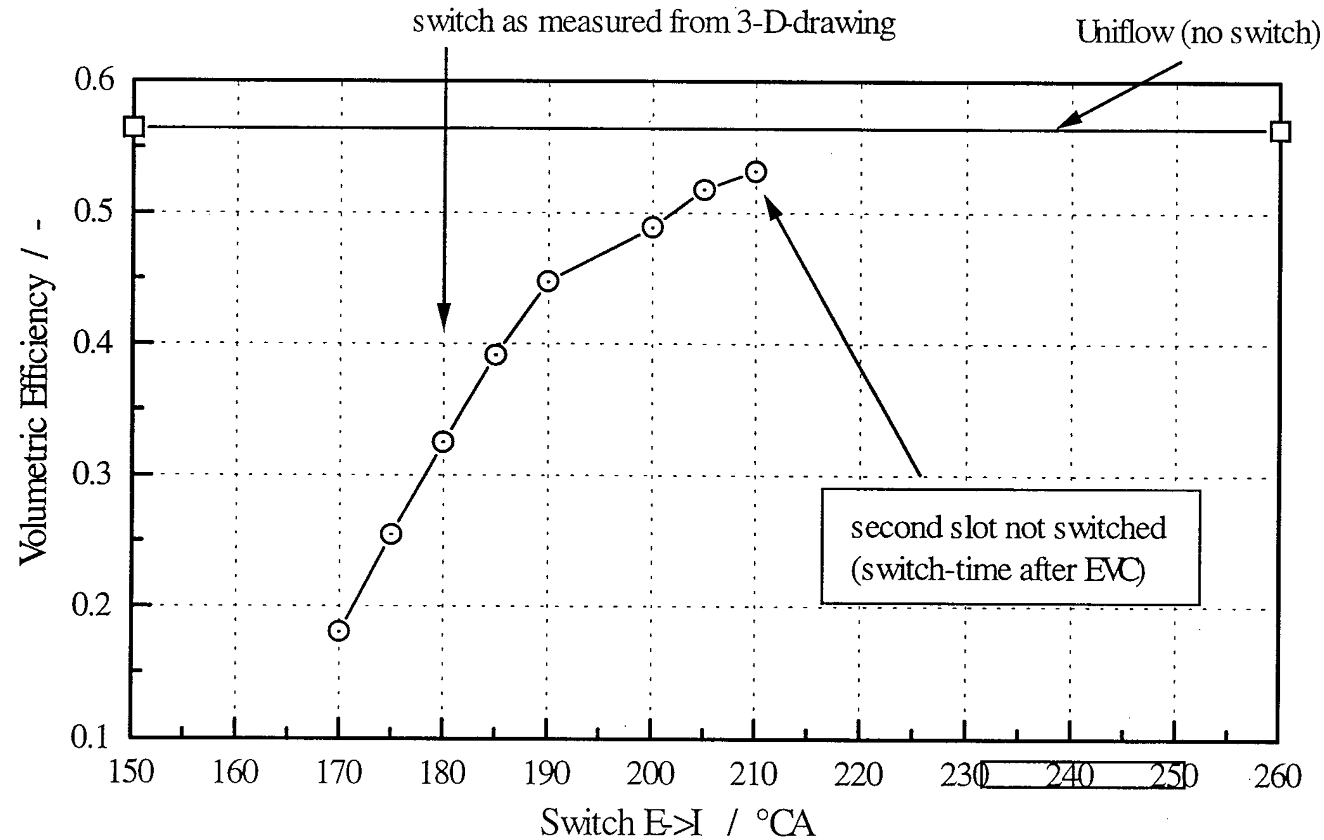

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Figure 1.1.2 - 6

Effects of Optimization of the First Intake/Exhaust Switch on Cylinder Pressure and Mass Flow

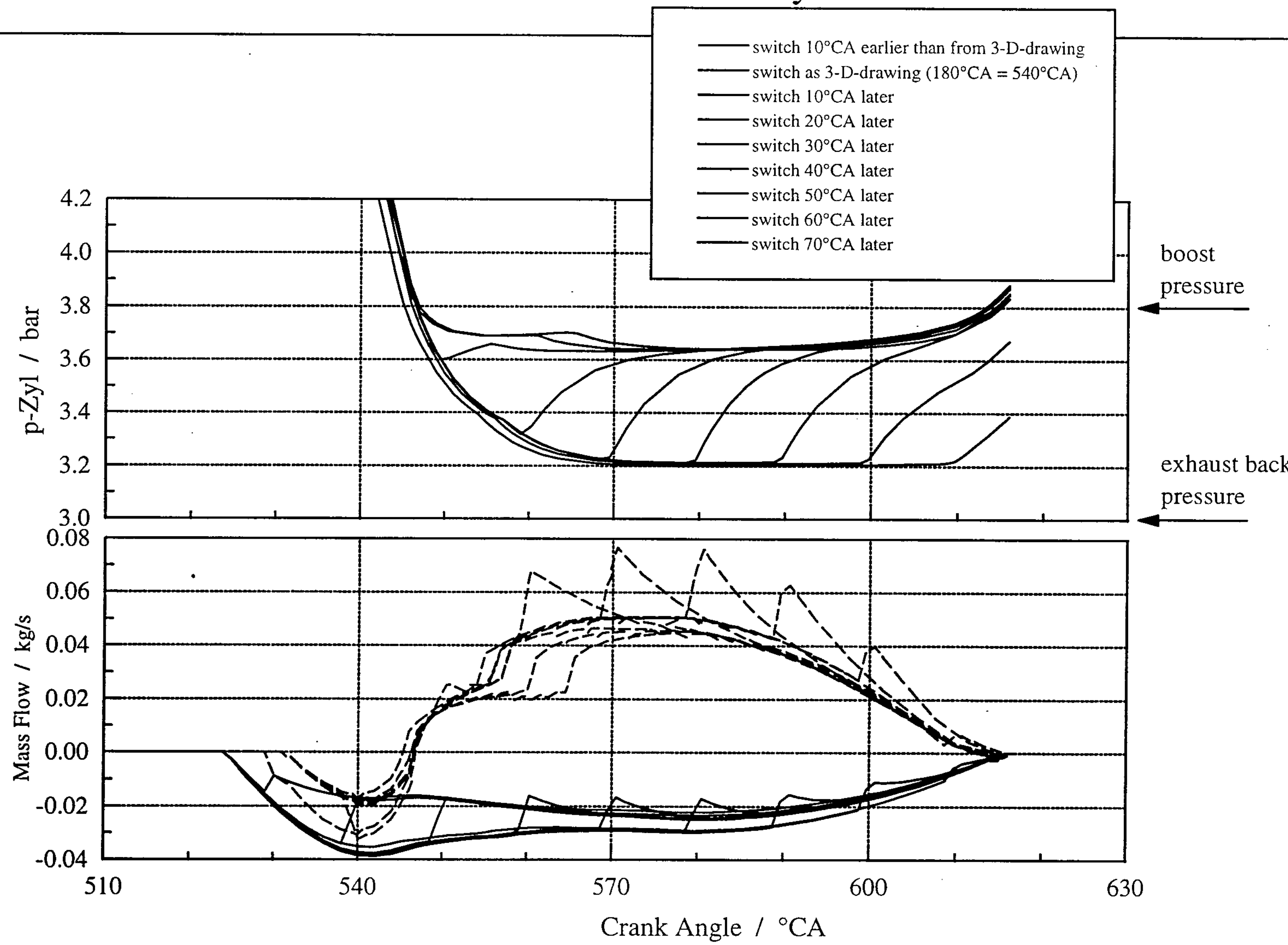

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Figure 1.1.2 - 7
Effects on Volumetric Efficiency due to Variation of Second Switch - 12.1 bar

First exhaust slot not switched, Variation of switch-time of second exhaust slot

Assumptions:

Ideal switch (no time delay between EVC and IVO)

Minimum valve area is slot area; open area of rotational valve always is larger than slot area)

IMEP = 12.1 bar
mBR / Asp = 65 mg

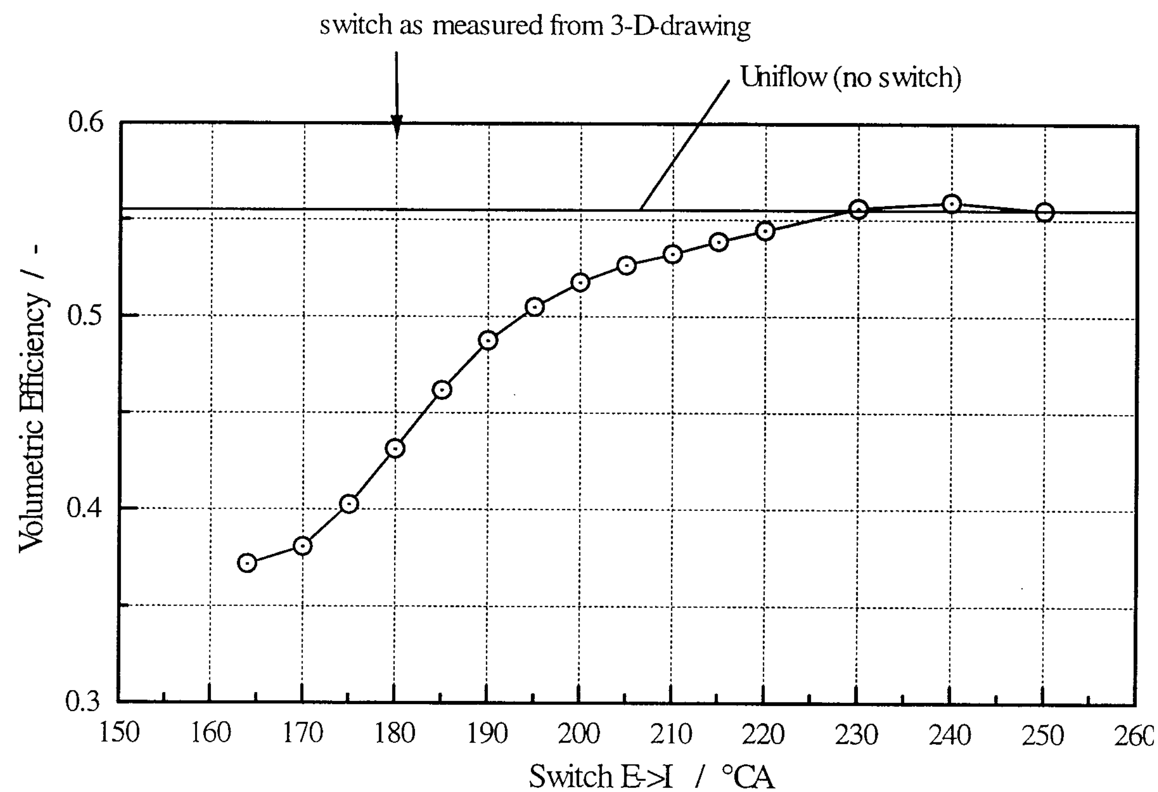

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Figure 1.1.2 - 8
Effects on Volumetric Efficiency due to Variation of Second Switch - 16.7 bar

First exhaust slot not switched, Variation of switch-time of second exhaust slot

Assumptions:

Ideal switch (no time delay between EVC and IVO)

Minimum valve area is slot area; open area of rotational valve always is larger than slot area)

IMEP = 16.7 bar
mBR / Asp = 90 mg

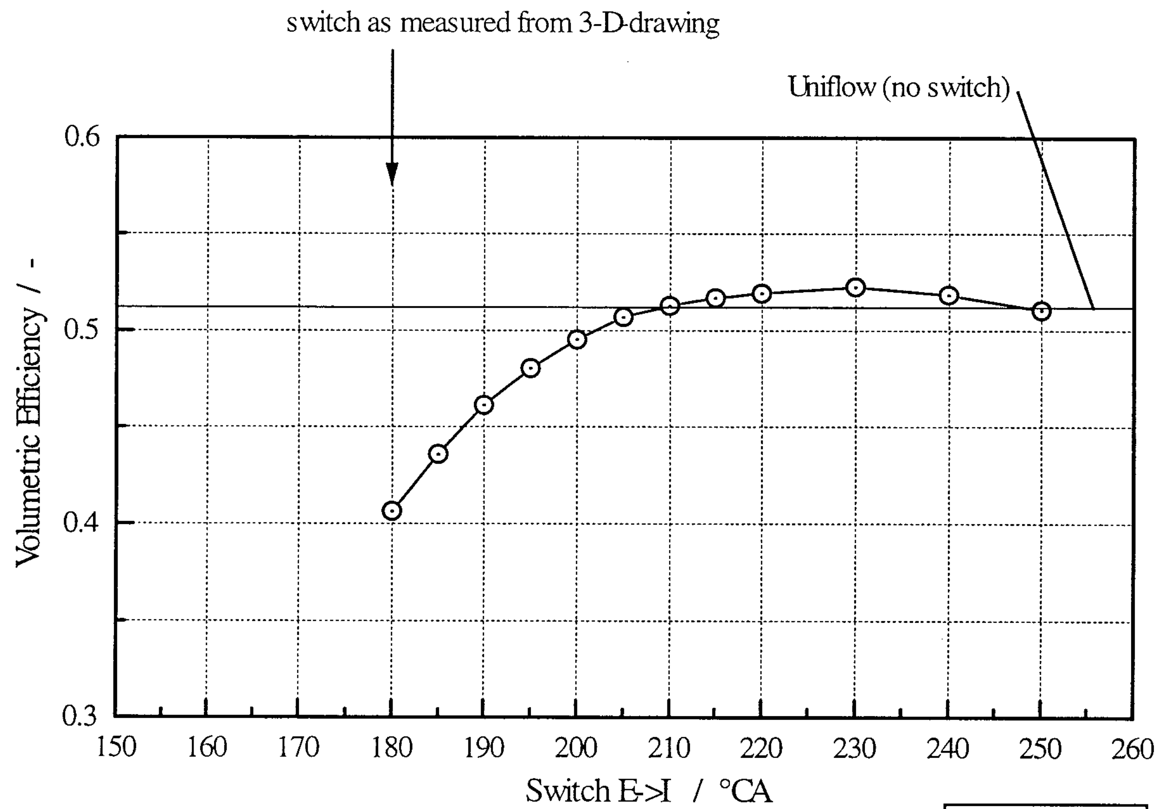

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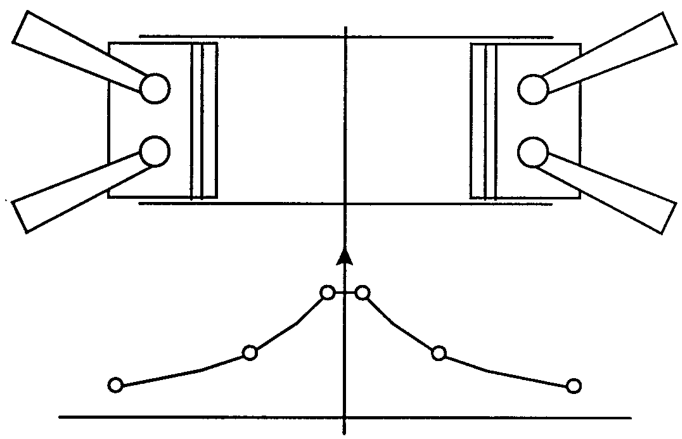
Figure 1.1.2 - 9
Boundary Conditions for Evaluation of Potential ISFC and Power



assumed surface temperatures:

- piston: 600 K
- Cylinder liner:

Distance from TDC [mm]	Temperature [K]
0	580
30	480
90	420

Figure 1.1.2 - 10
ISFC versus Combustion Induced Pressure Rise

First exhaust slot not switched, second exhaust slot switched at 220°CA (optimized gas exchange)

Boundary conditions:
rel AFR = appr 1.45 (base)
IMEP = 20.2 bar
Boost pressure = 4.0 bar
Exhaust back pressure = 3.0 bar
Combustion duration = 65°CA

Variation:
Compression ratio = 19.5 - 27.5
Max. Pressure = 250 - 390 bar

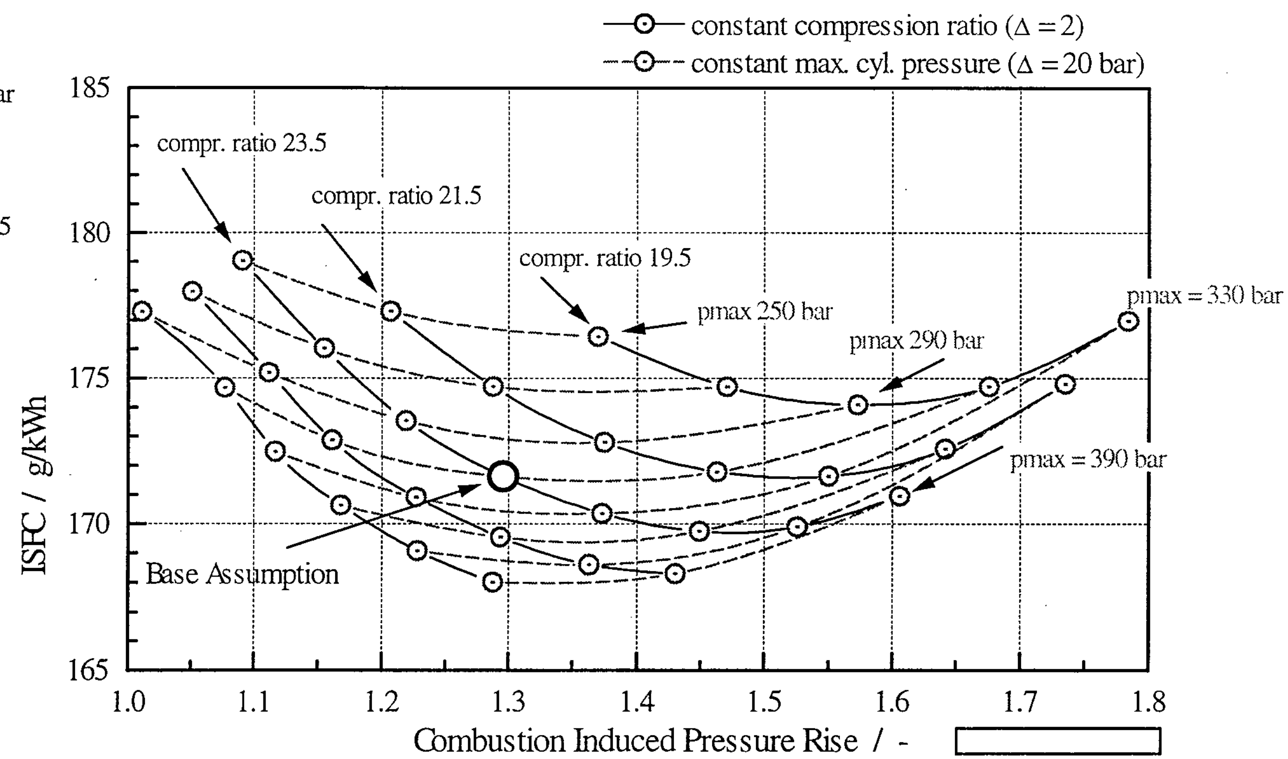


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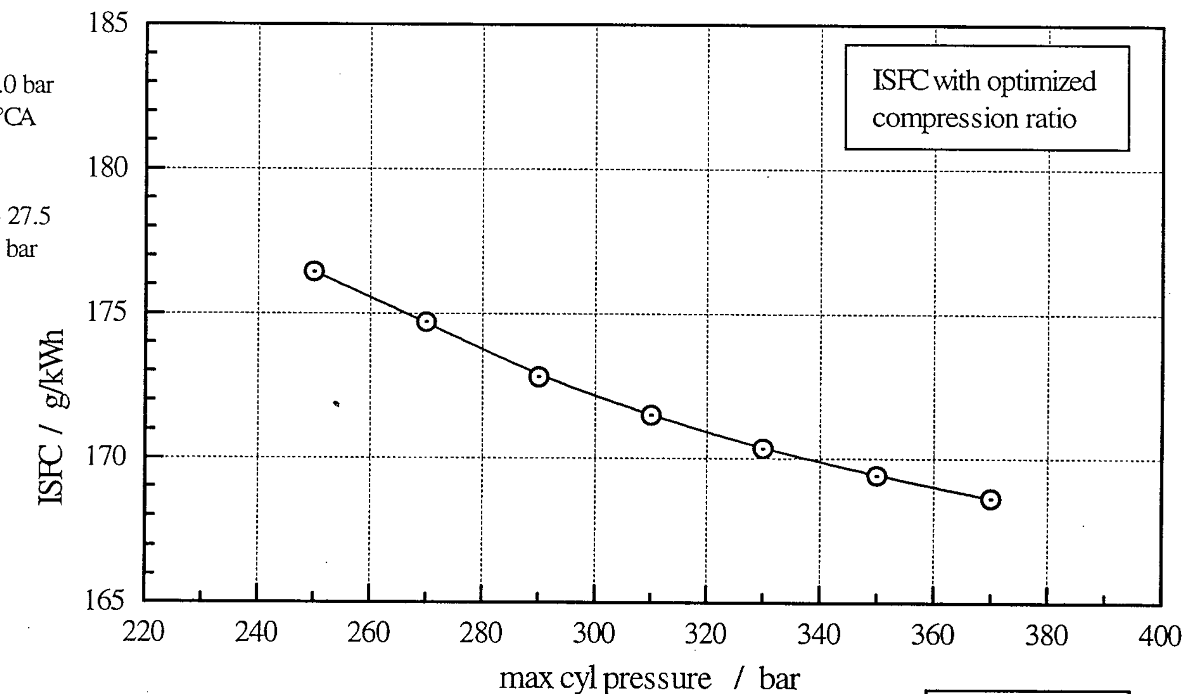
Figure 1.1.2 - 11

ISFC versus Maximum Cylinder Pressure

First exhaust slot not switched, second exhaust slot switched at 220°CA (optimized gas exchange)

Boundary conditions:
rel AFR = appr 1.45 (base)
IMEP = 20.2 bar
Boost pressure = 4.0 bar
Exhaust back pressure = 3.0 bar
Combustion duration = 65°CA

Variation:
Compression ratio = 19.5 - 27.5
Max. Pressure = 250 - 370 bar



FEV Engine Technology

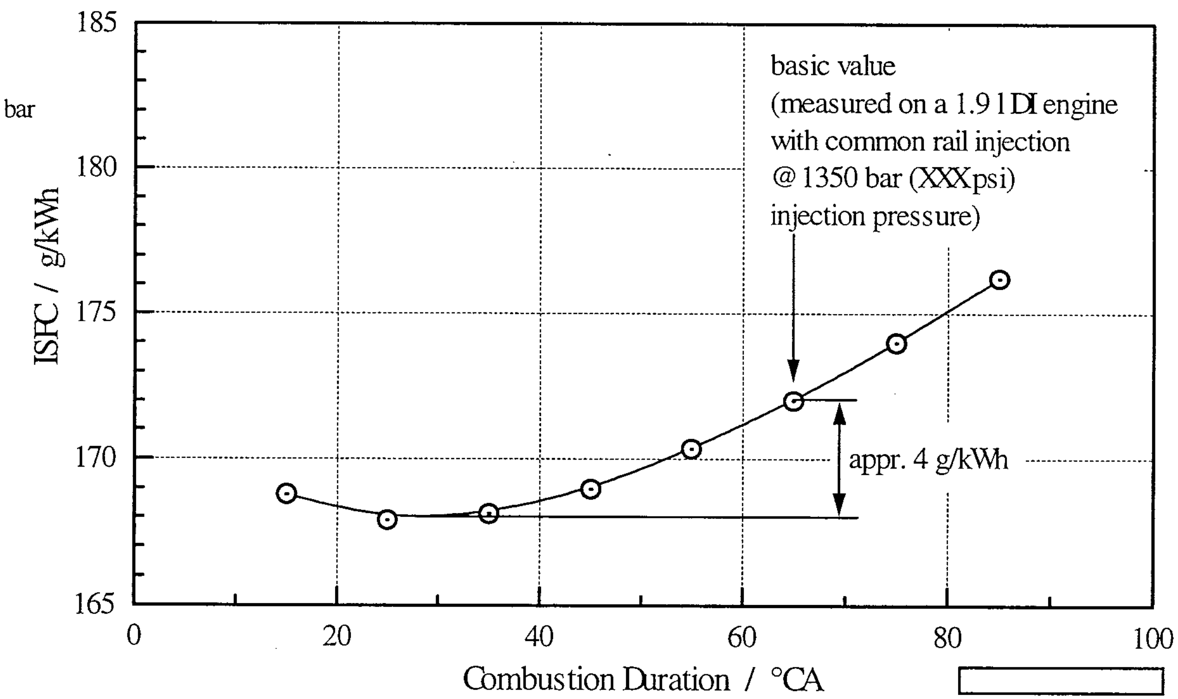
Figure 1.1.2 - 12
Influence of Combustion Duration on ISFC

First exhaust slot not switched, second exhaust slot switched at 220°CA (optimized gas exchange)

Boundary conditions:
rel AFR = appr 1.45
IMEP = 20.2 bar
Max. Pressure = 310 bar

Boost pressure = 4.0 bar
Exhaust back pressure = 3.0 bar
Compression ratio = 23.5

Variation:
Combustion duration =
15 - 85°CA

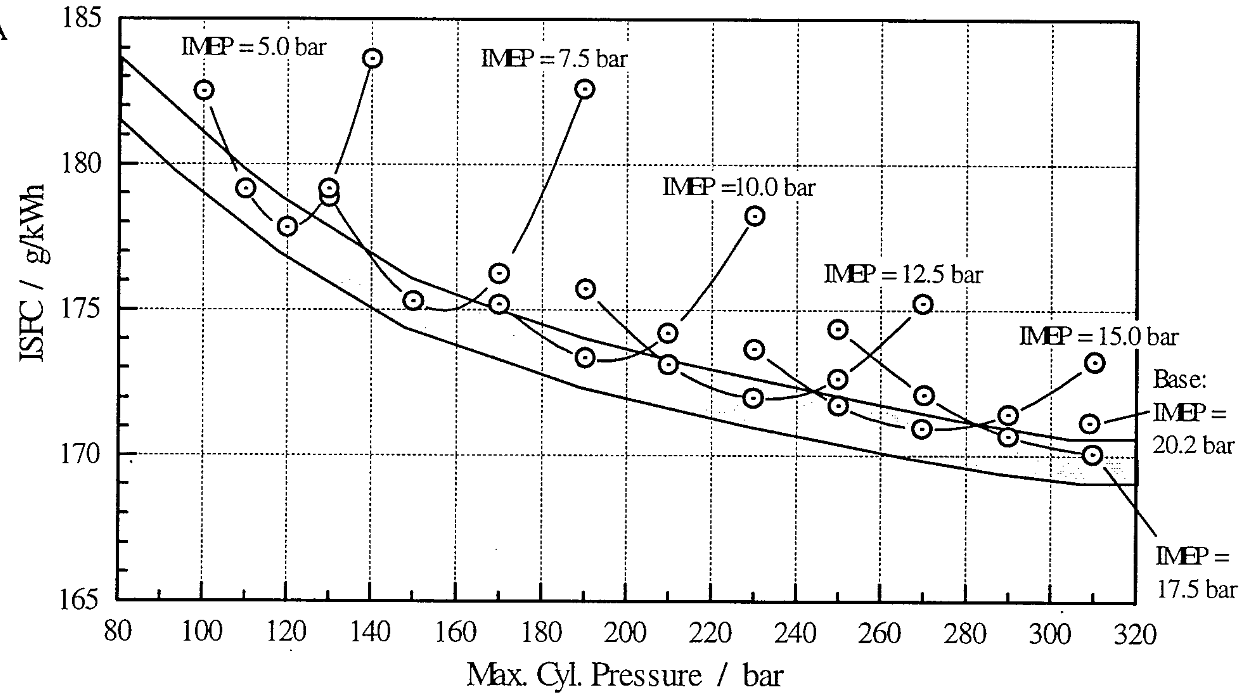


Engine Technology

Figure 1.1.2 - 13
Investigation of the effects of Various IMEPs on Fuel Consumption (ISFC)

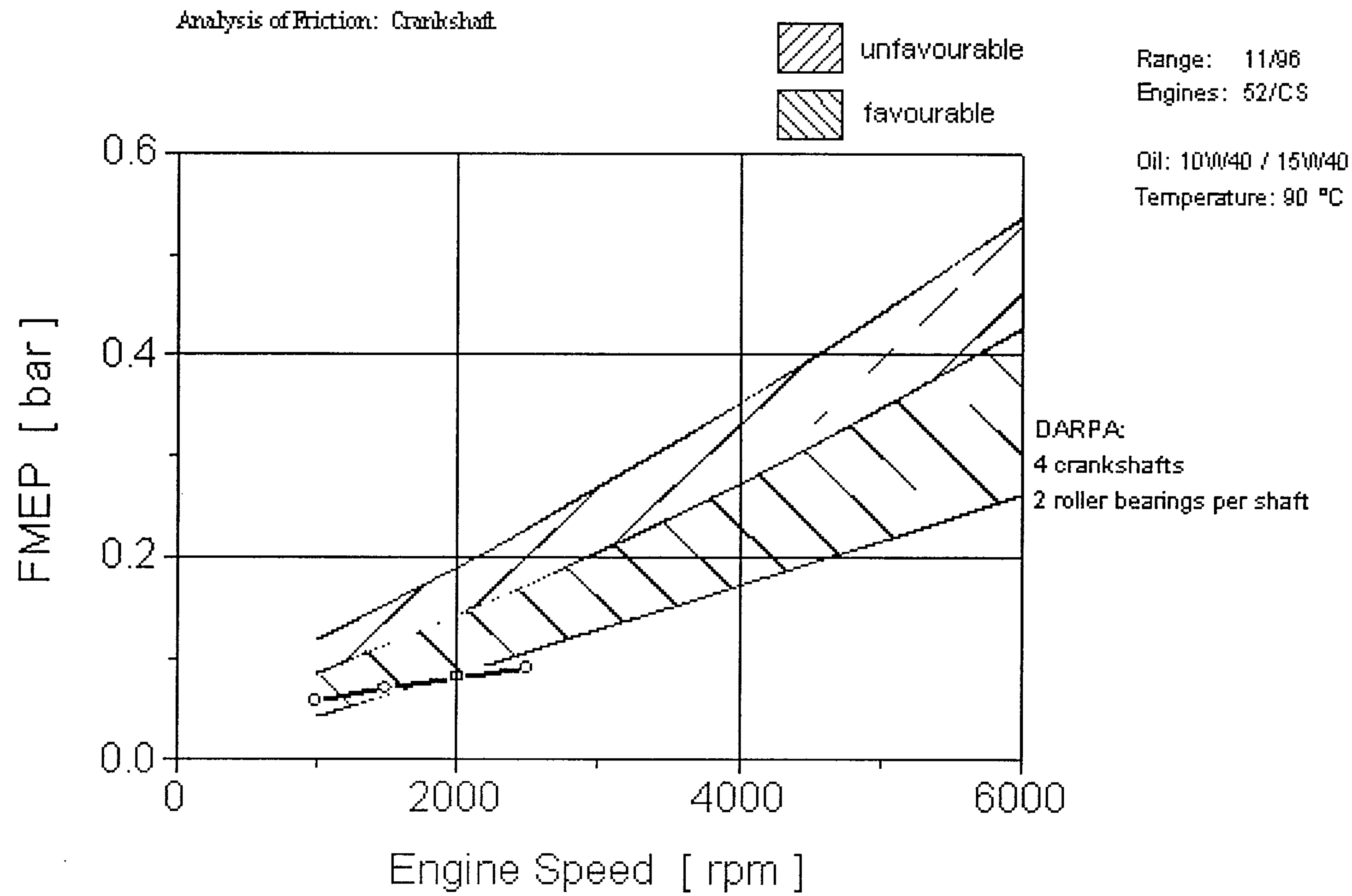
First exhaust slot not switched, second exhaust slot switched at 220°CA (optimized gas exchange)

Boundary conditions:
rel AFR = appr 1.45
Compression ratio = 23.5
Combustion duration = 65°CA



FEV Engine Technology

Figure 1.2.1 - 1
Analysis of Friction for the TECE Crankshaft



FEV Engine Technology

Figure 1.2.1 - 2
Analysis of Friction for Piston Group and Connecting Rod Bearings

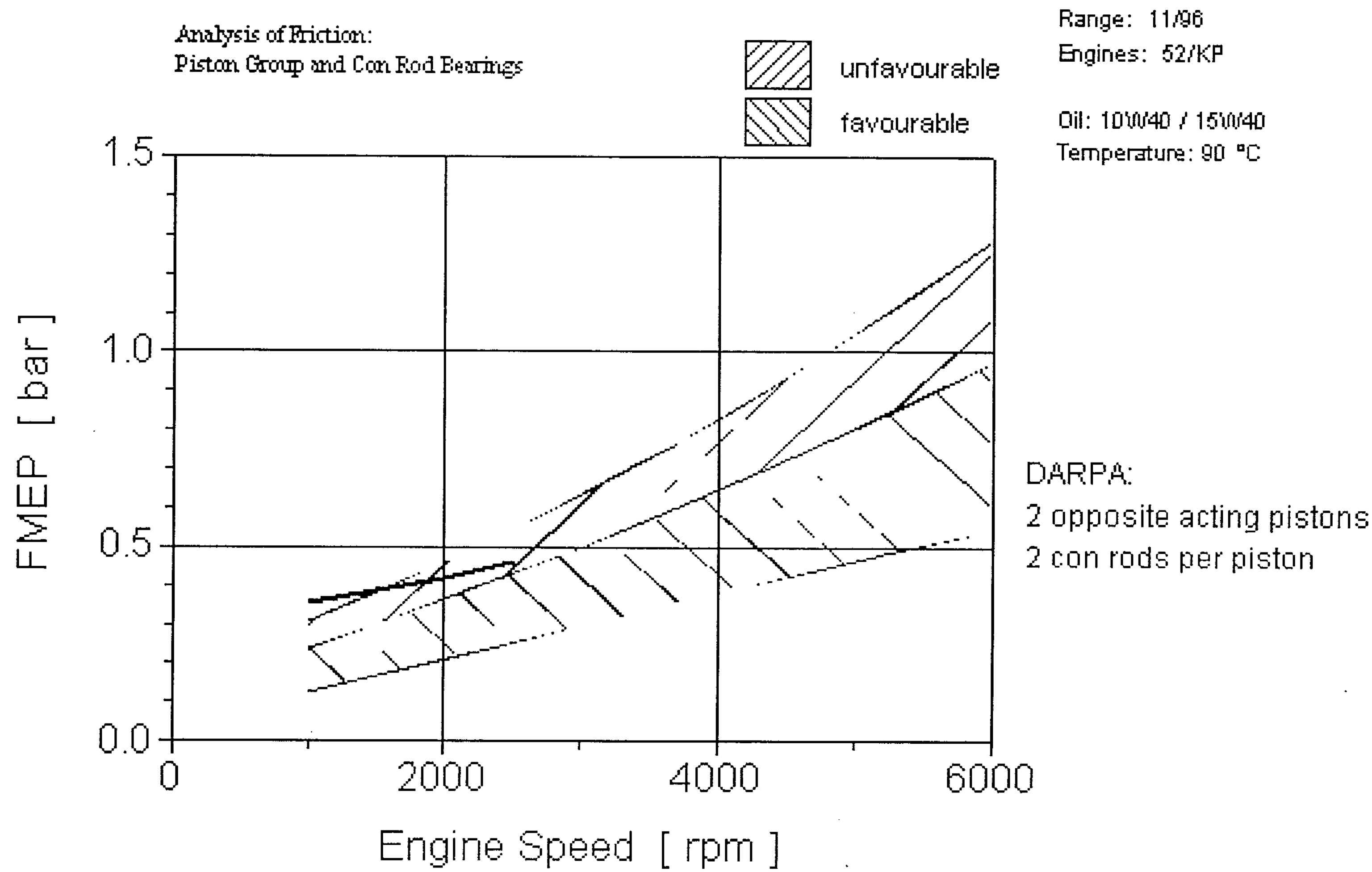


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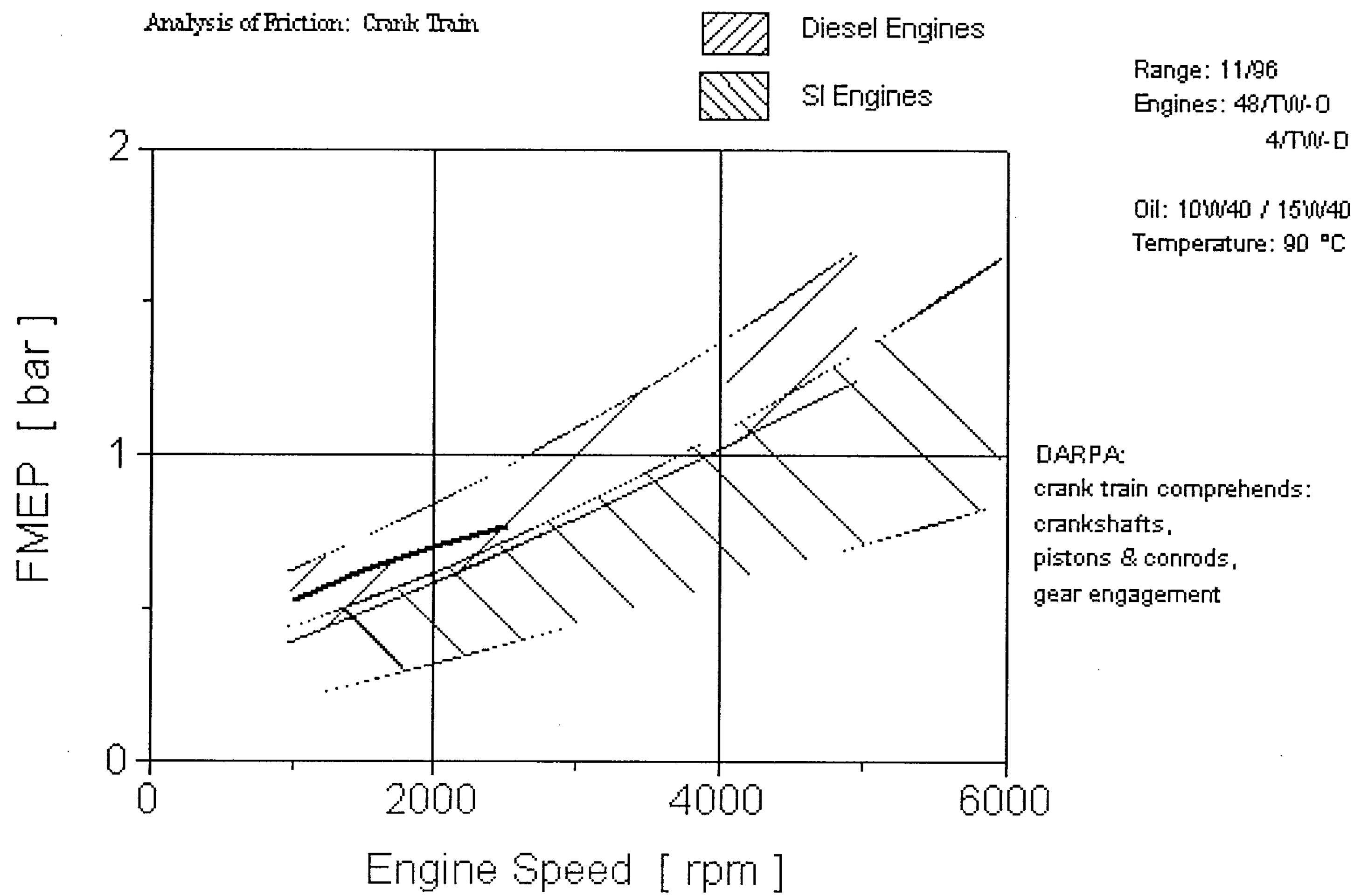
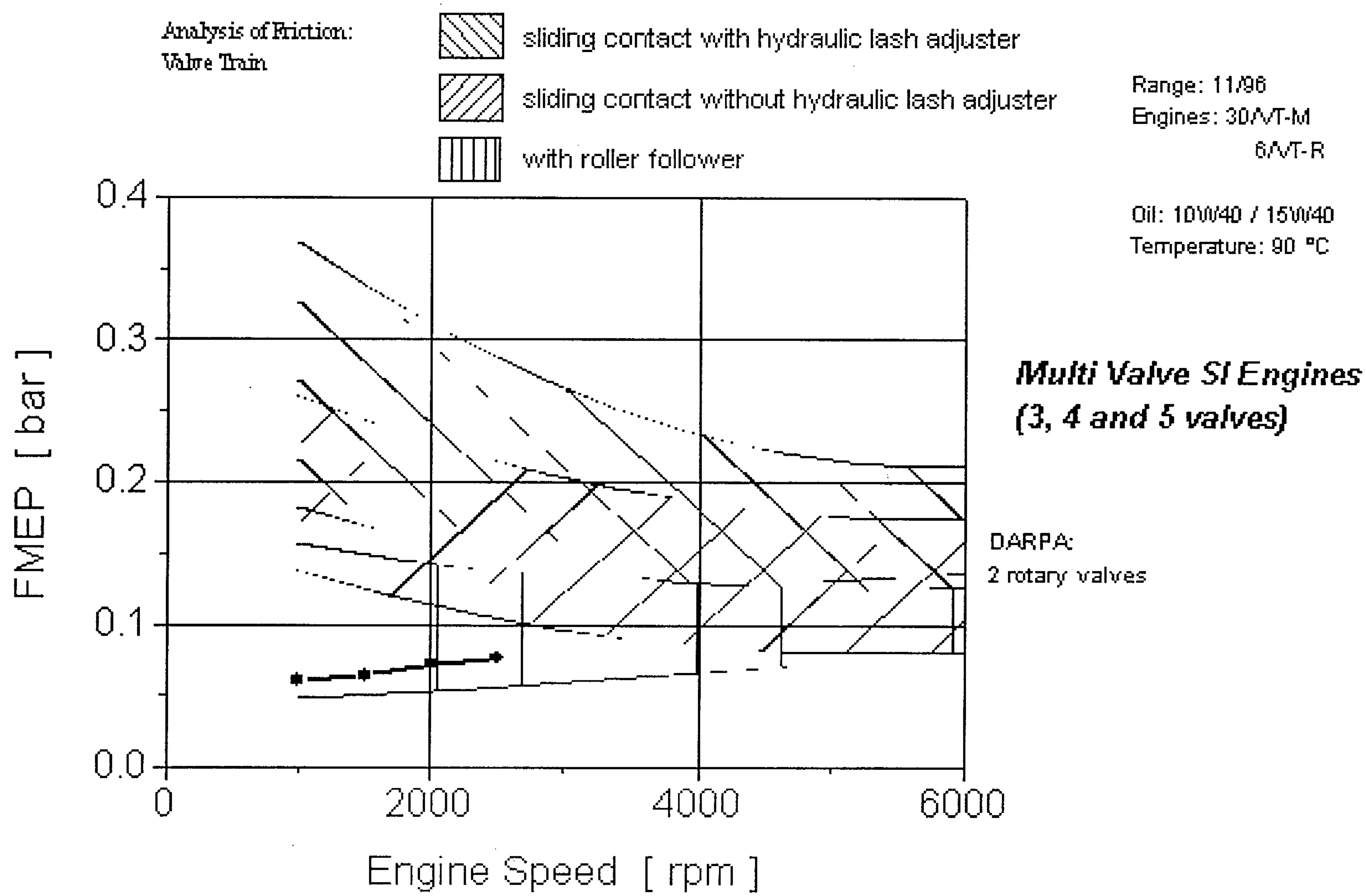
Figure 1.2.1 - 3
Analysis of Friction for Crank Train



FEV Engine Technology

Figure 1.2.1 - 4
Analysis of Friction for Valve Train



FEV Engine Technology

Figure 1.2.1 - 5
Analysis of Friction for Oil Circulation Circuit

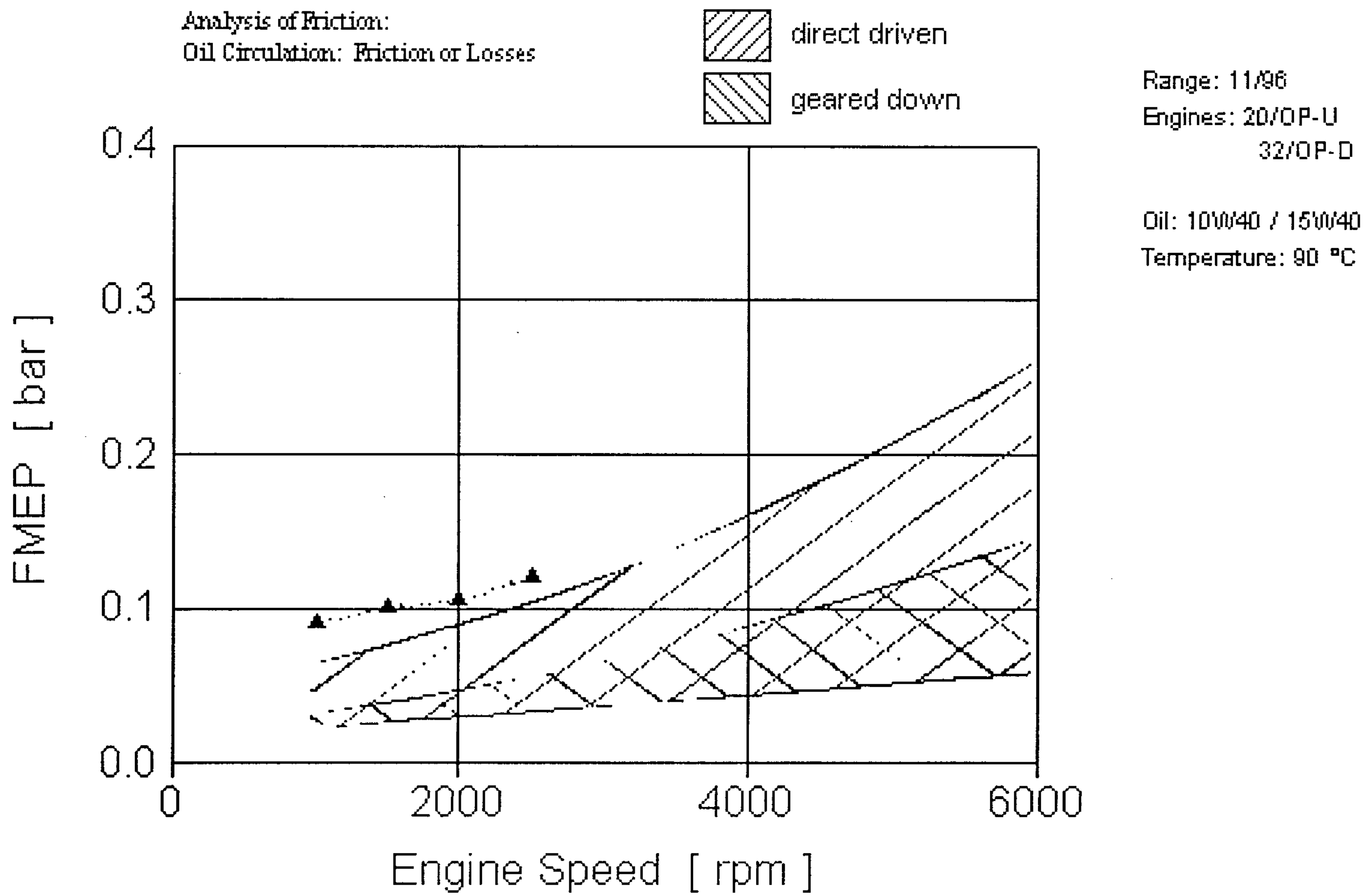


Figure 1.2.1 - 6
Analysis of Friction for Loaded Water Pump

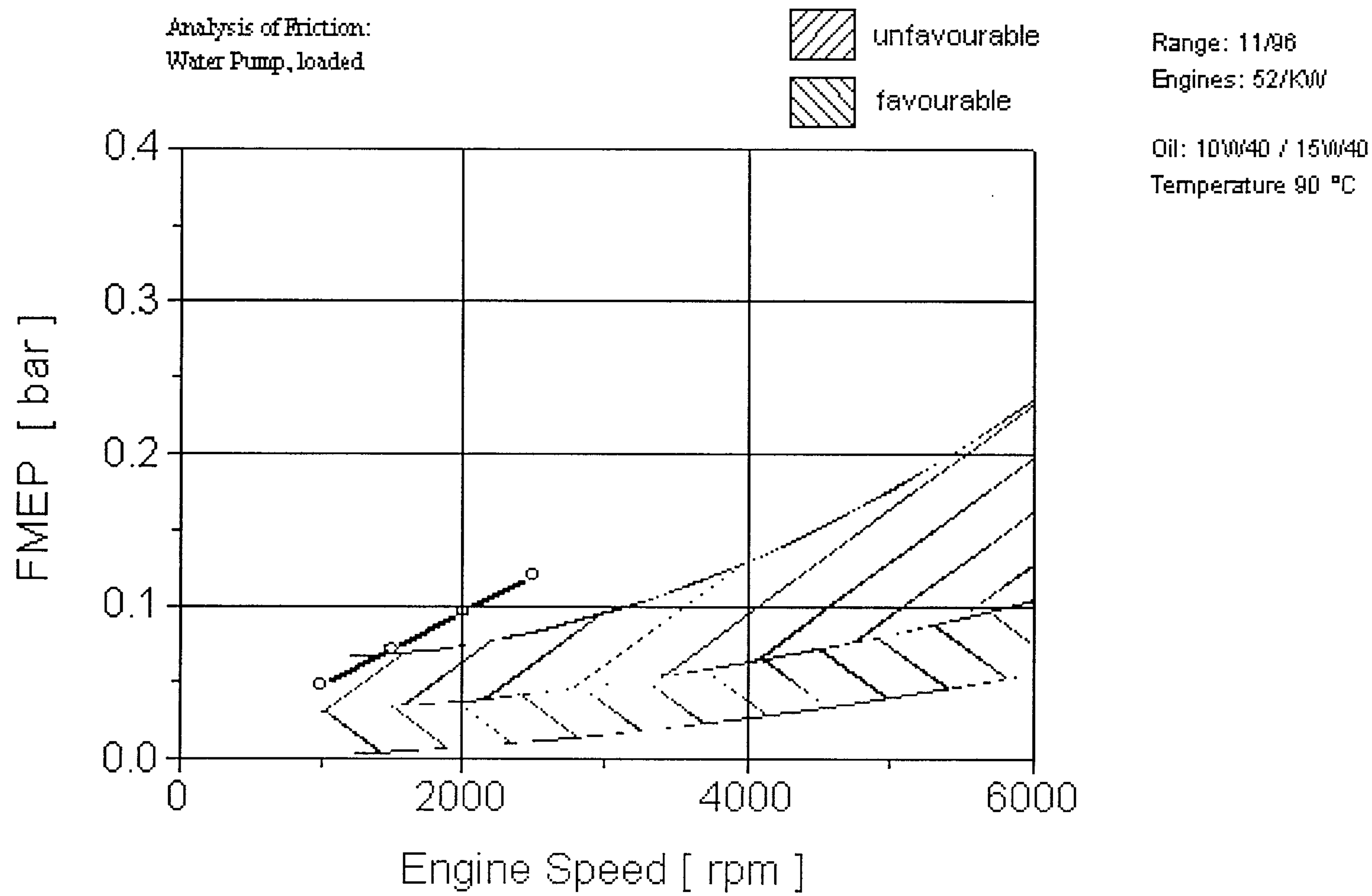


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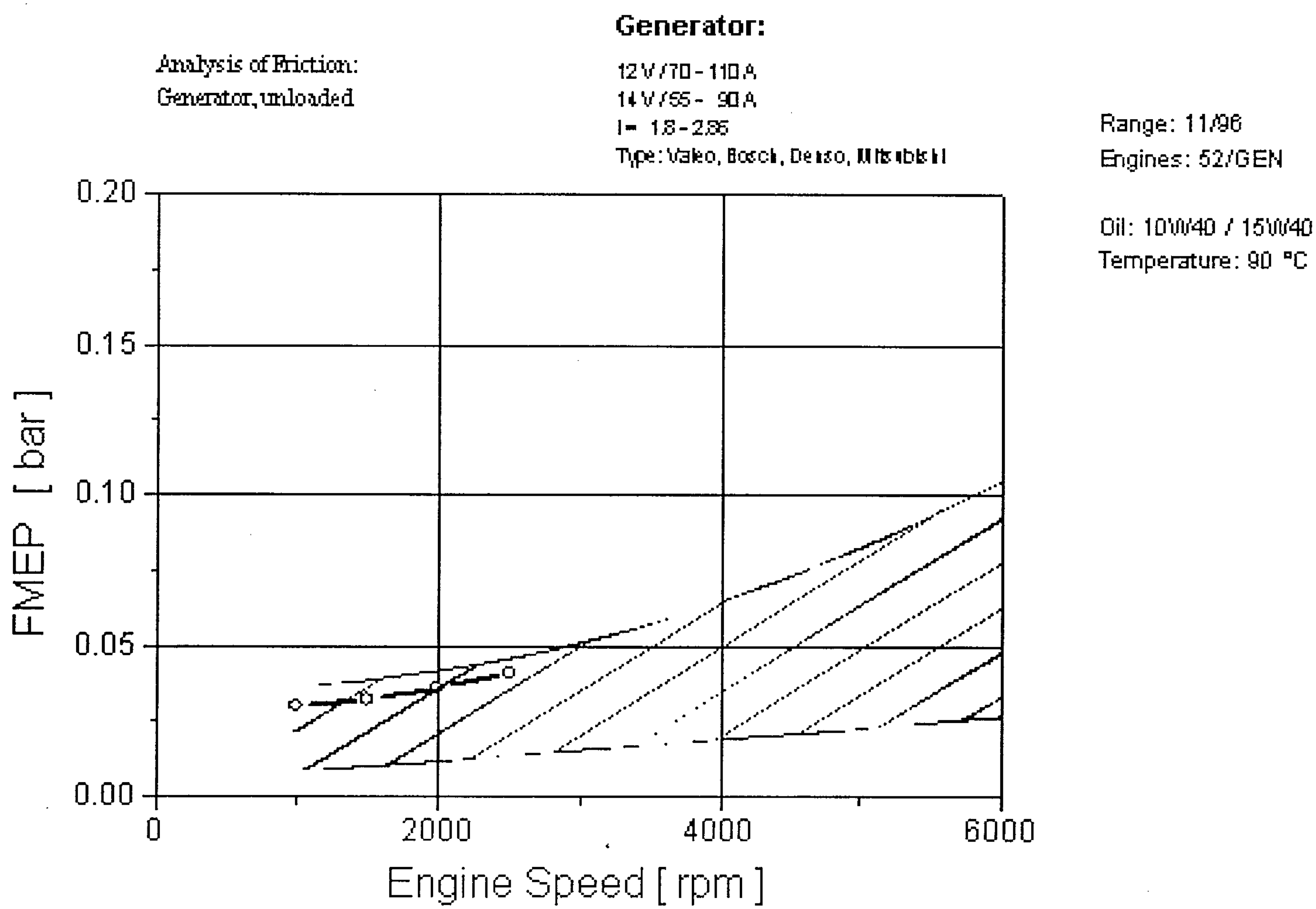
Figure 1.2.1 - 7
Analysis of Friction for Unloaded Generator



FEV Engine Technology

Figure 1.2.1 - 8
Analysis of Friction of the Complete TECE

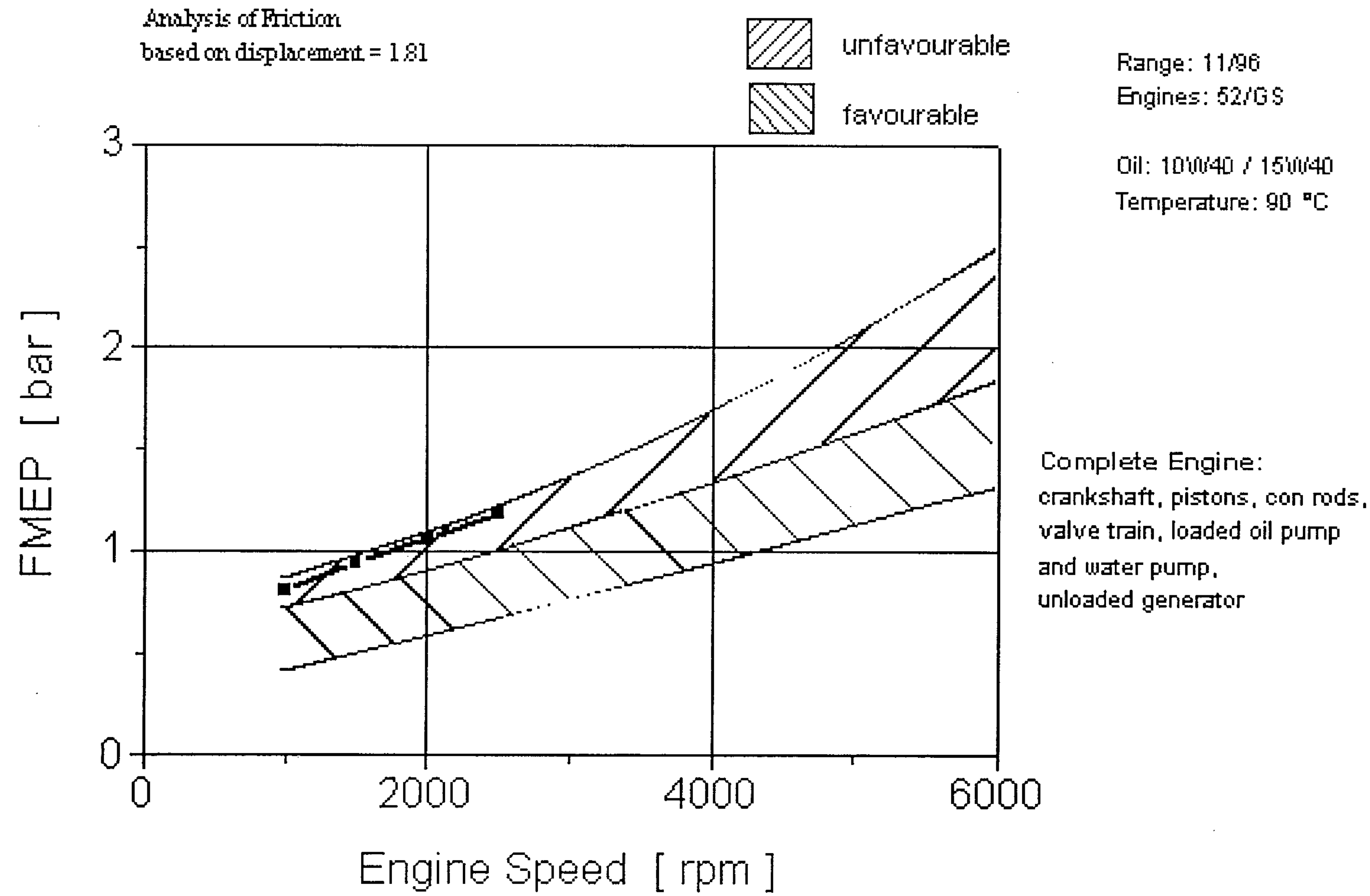


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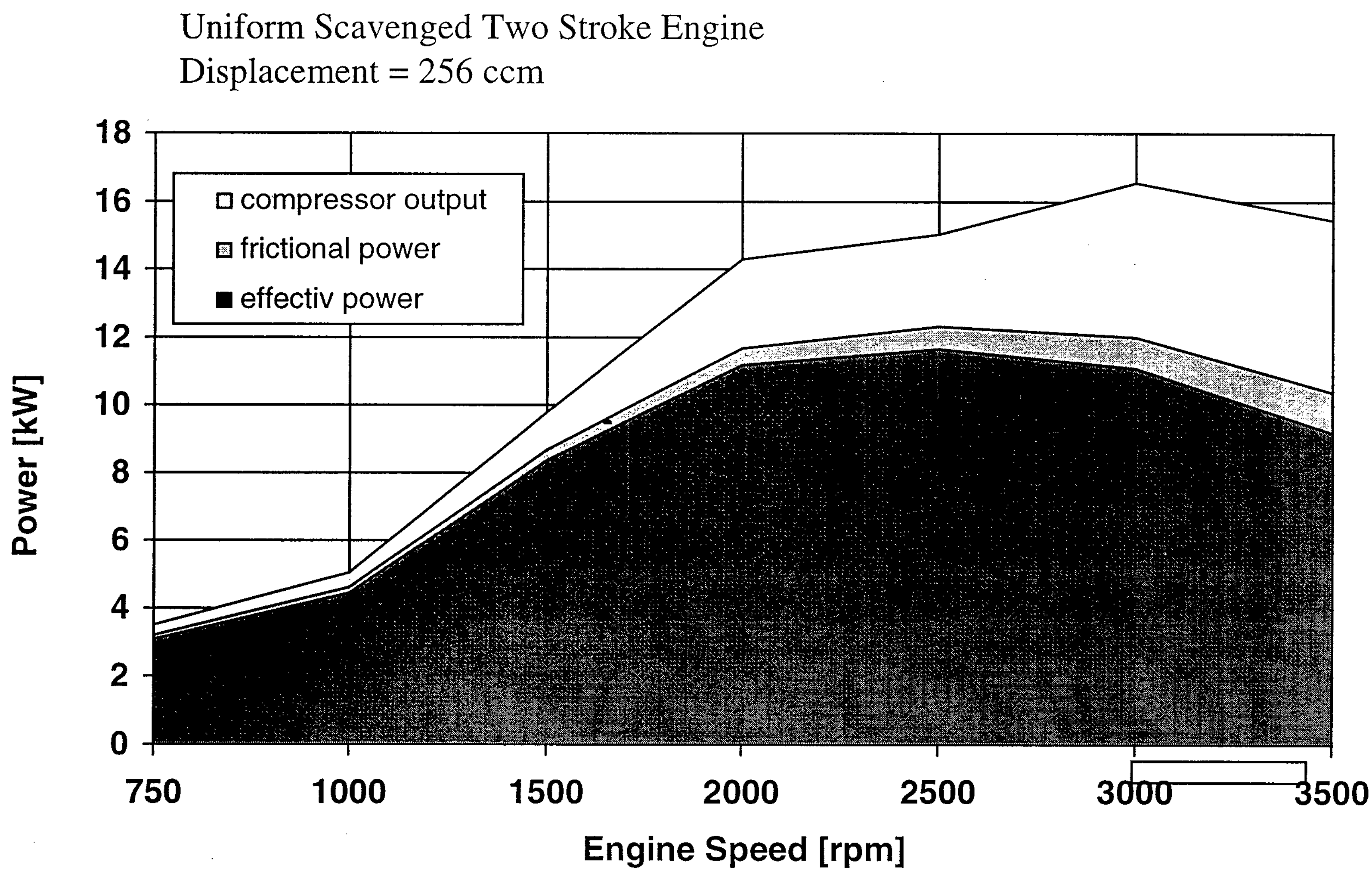
Figure 2.1.1 - 1

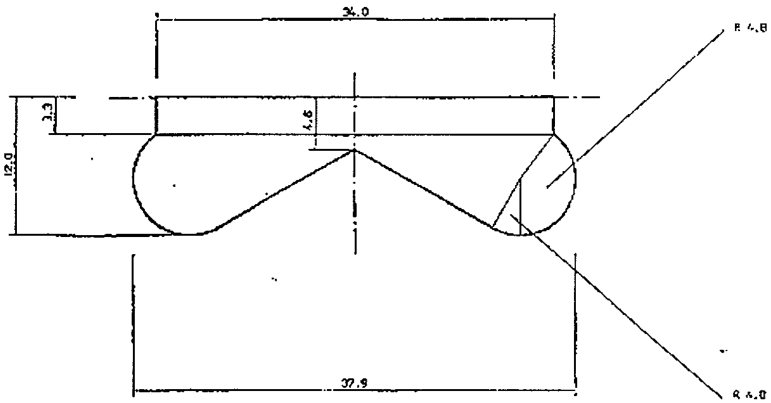
Comparison of Power Requirements versus Engine Speed



FEV Engine Technology

Figure 2.1.1 - 2
Two Variations for Piston Bowl Designs

Variation 1



Variation 2

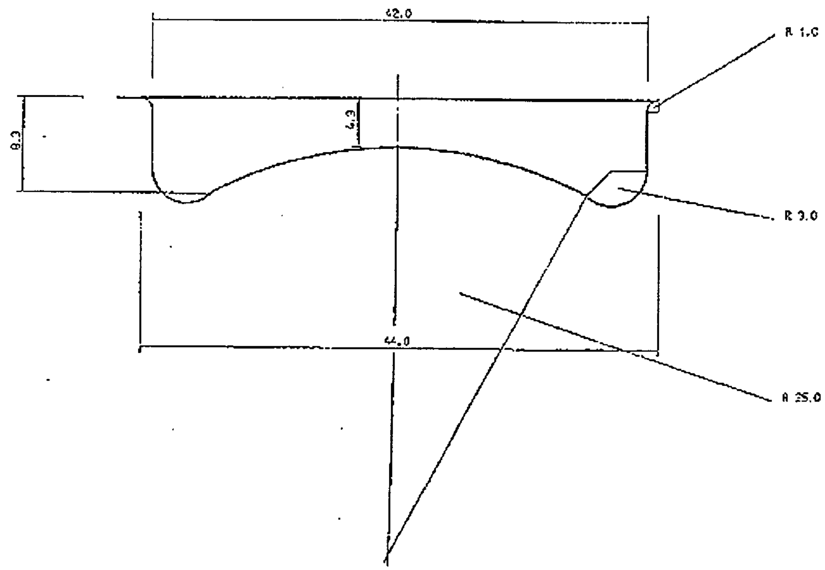


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Figure 2.1.1 - 3
Effects of the Various Piston Bowl Designs

Uniform Scavenged Two Stroke DI Diesel Engine

Displacement = 256 ccm

Influence of the Piston Bowl Design

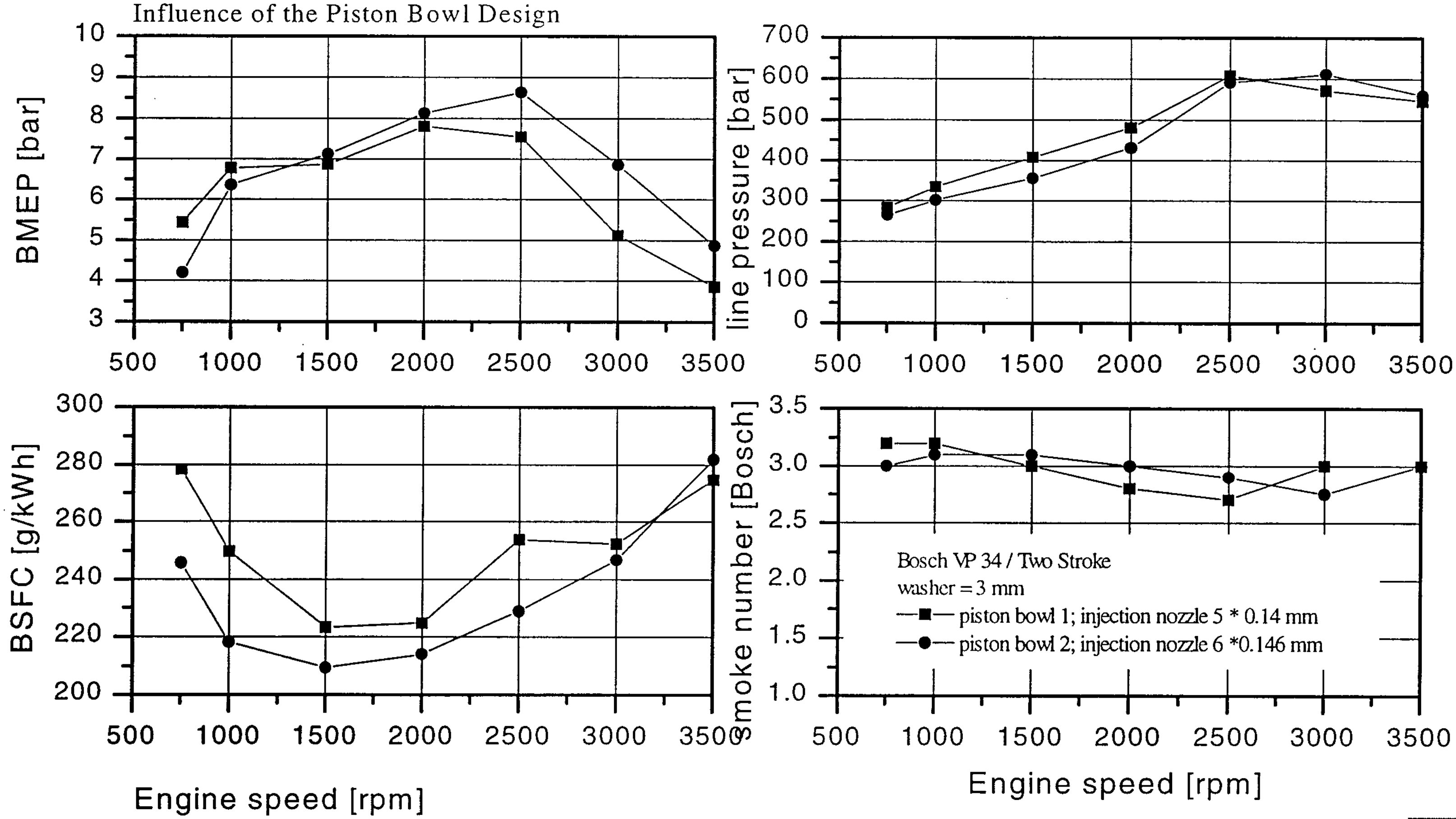

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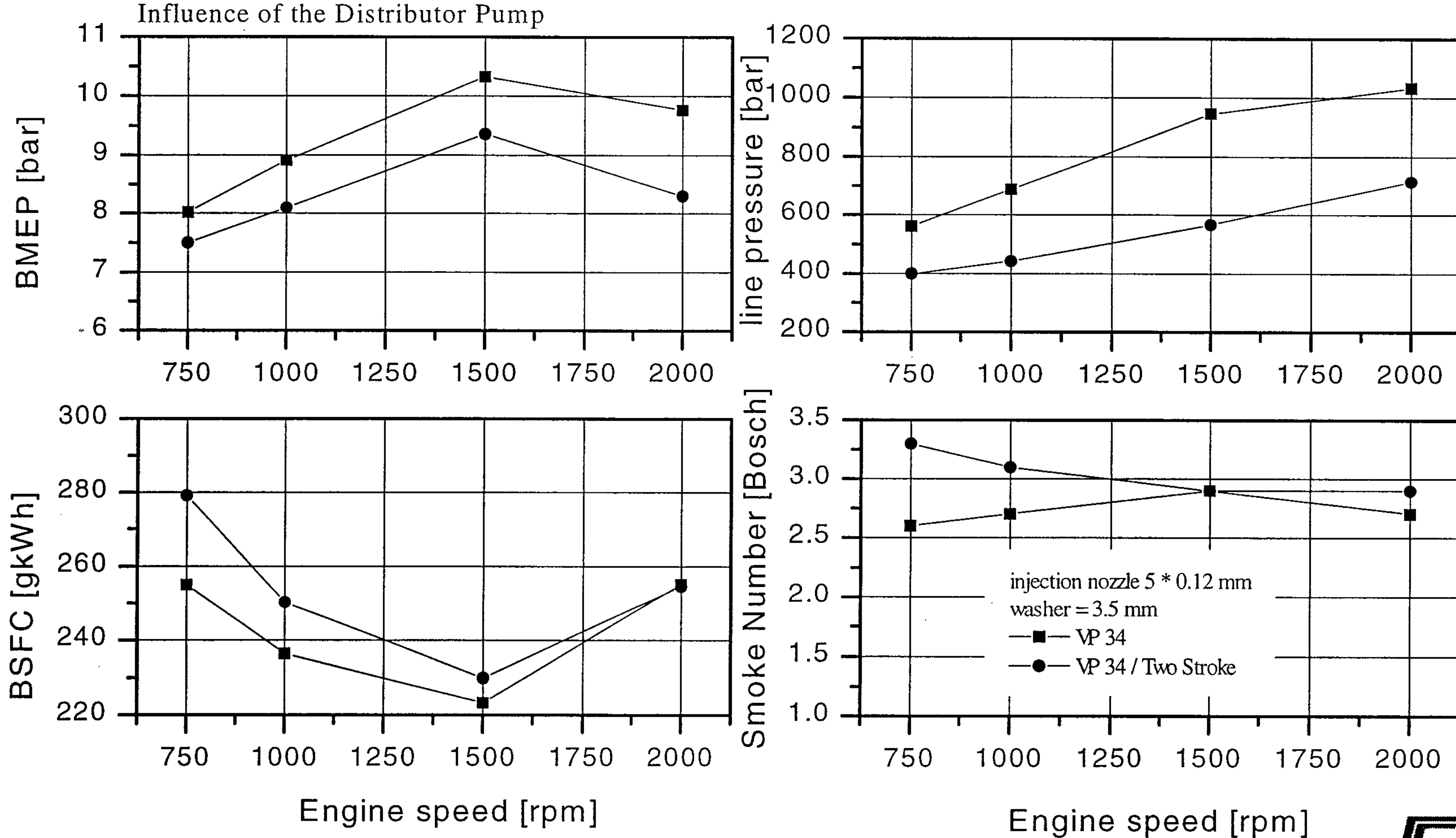
Figure 2.1.1 - 4
Influence of Injection System Operation
on Various Engine Paramenters

Uniform Scavenged Two Stroke DI Diesel Engine

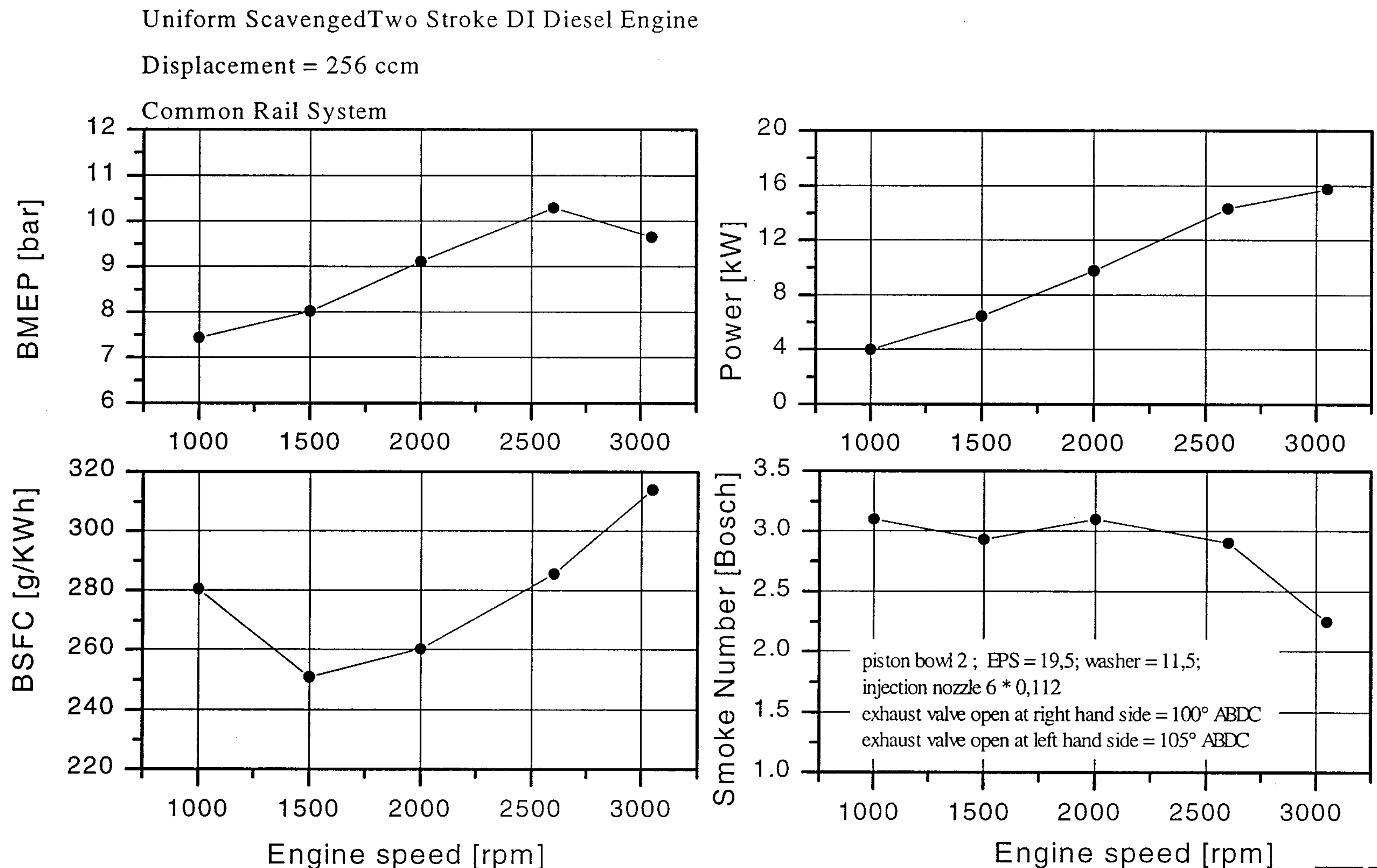
Displacement = 256 ccm

Influence of the Distributor Pump



FEV Engine Technology

Figure 2.1.1 - 5
Influence of Injection System Operation on Various Engine Paramenters



FEV Engine Technology

Figure 2.1.1 - 6
Cylinder Pressure Curve for
2 Stroke DI Diesel Engine

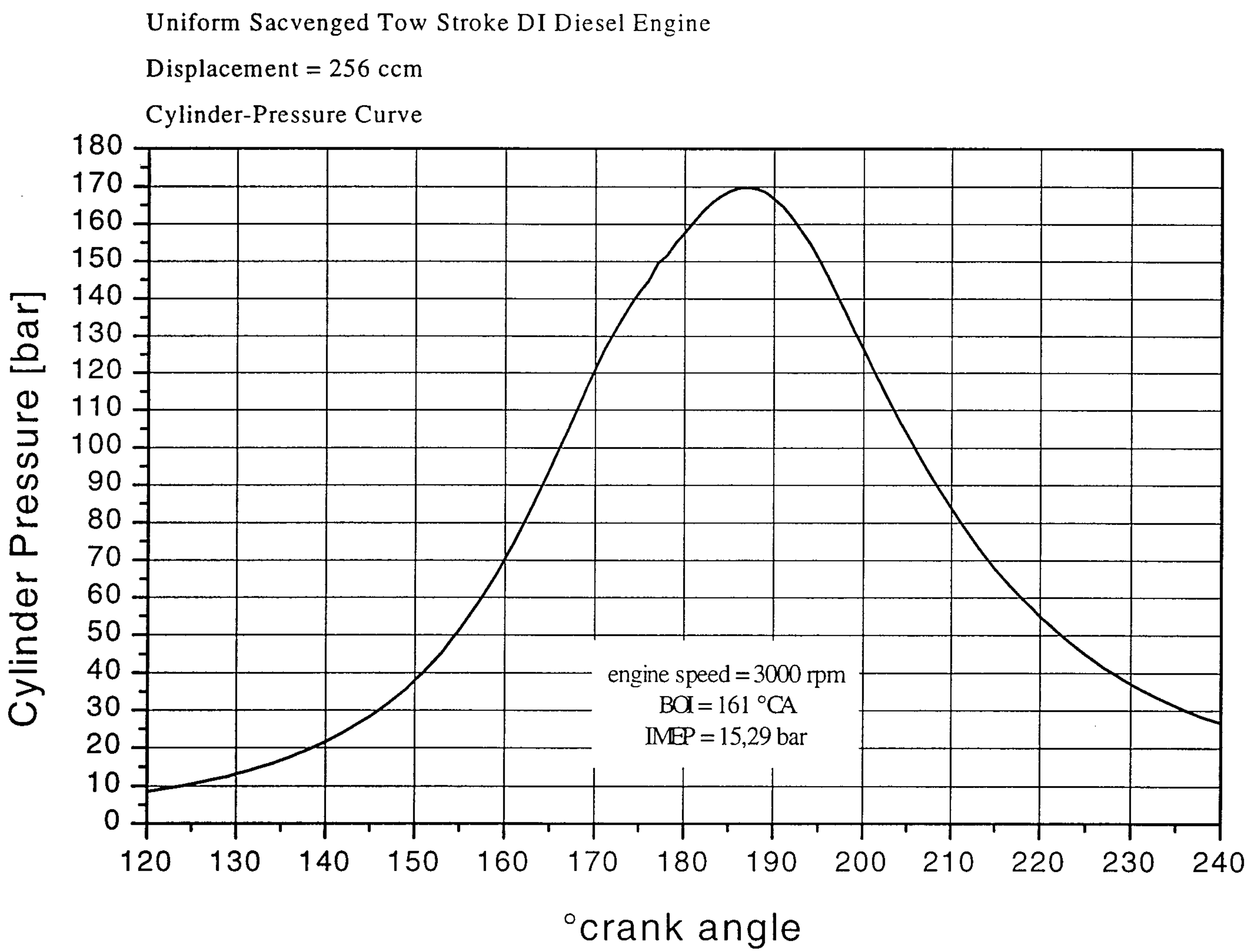


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Figure 2.1.2 - 1
Modeling of the 2 Stroke DI Diesel Engine

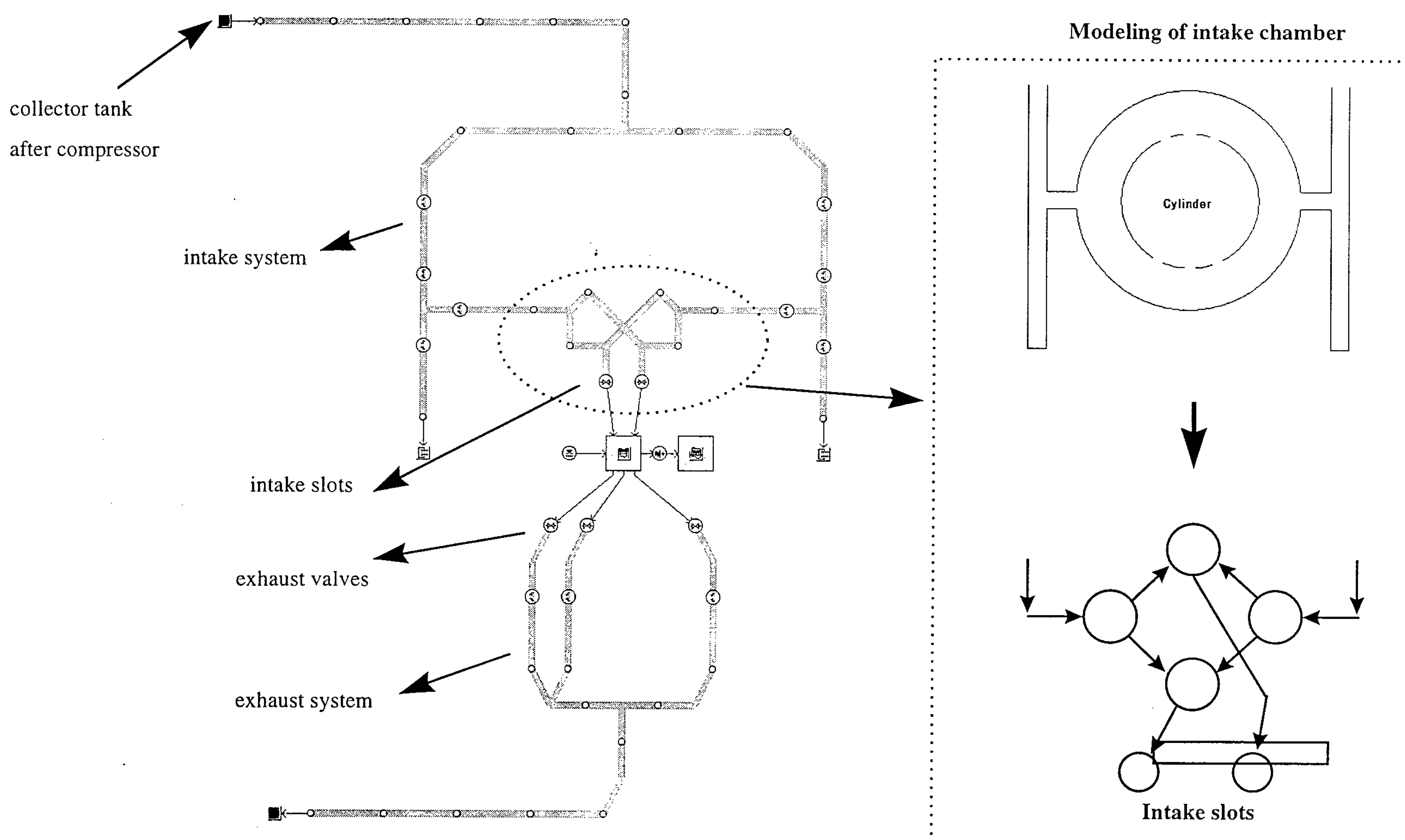

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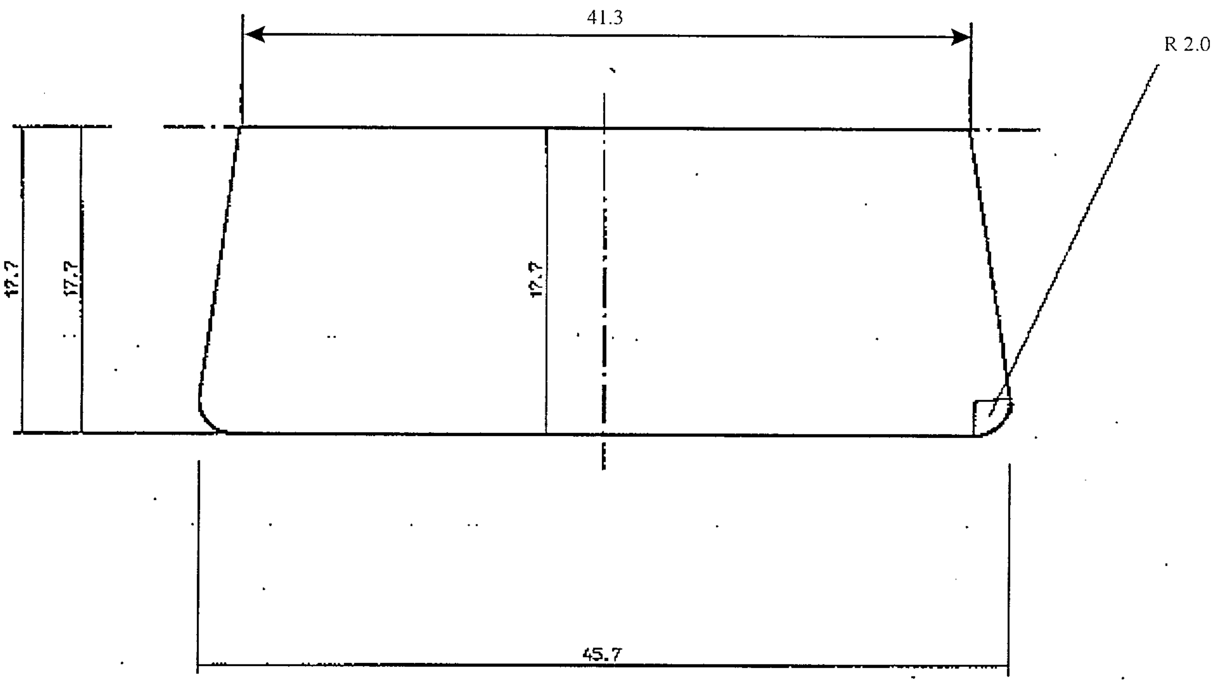
Figure 2.2.1 - 1
Piston Bowl Geometry for Four Stroke, 2-Valve Engine



FEV
Engine Technology

Figure 2.2.1 - 2

Test Bench Stup For Four Stoke Engine

Test Bench Setup

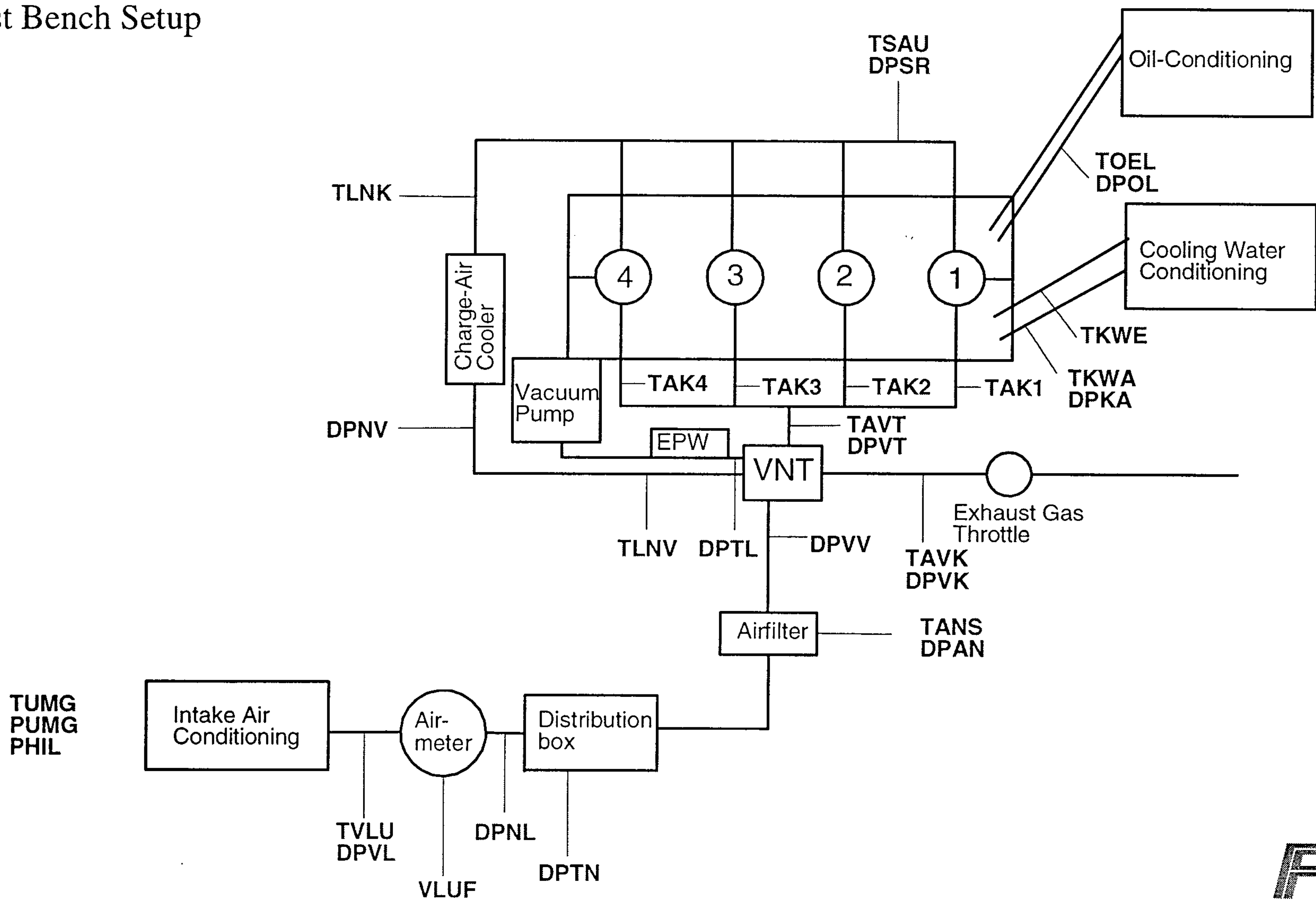


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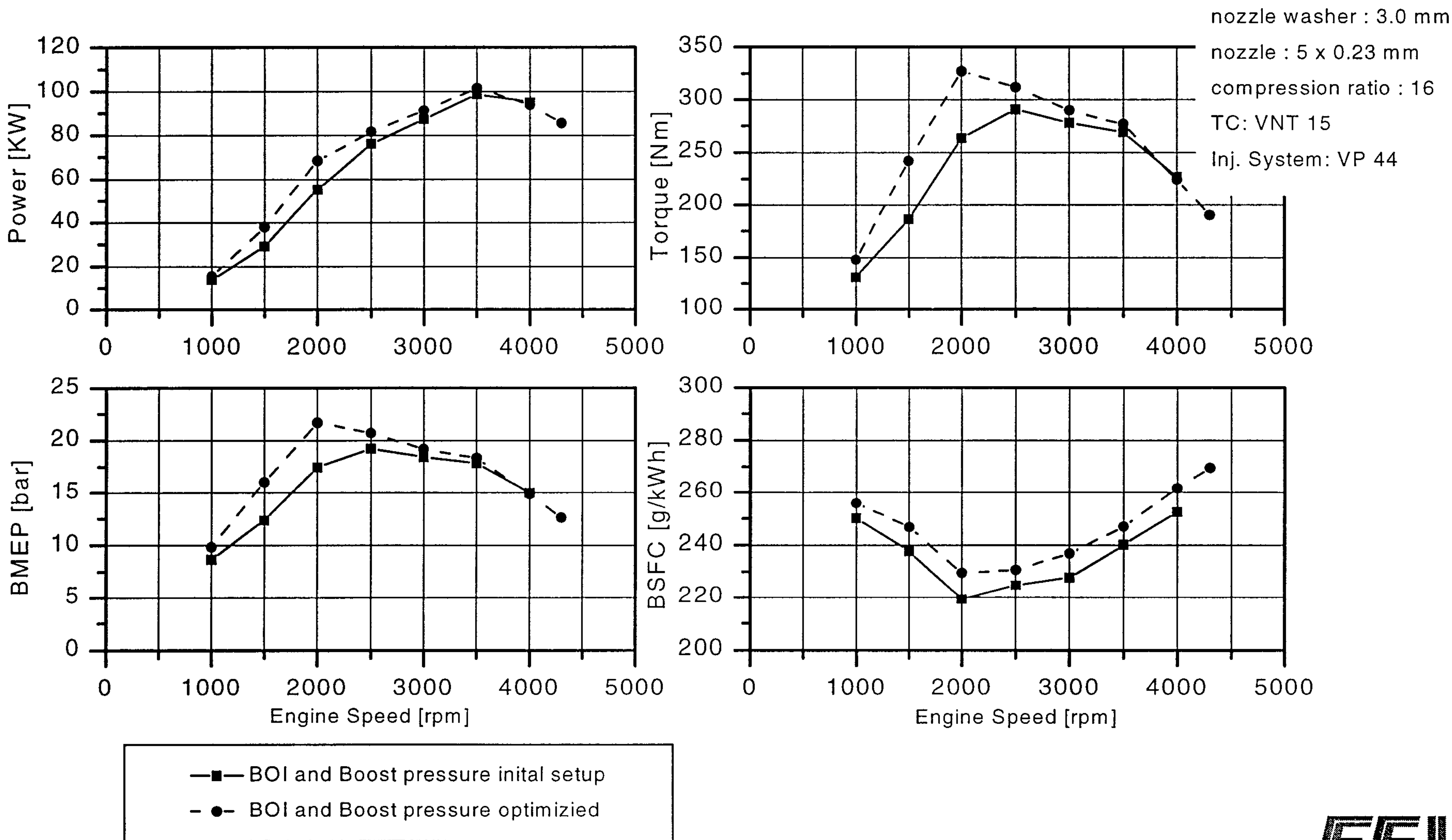
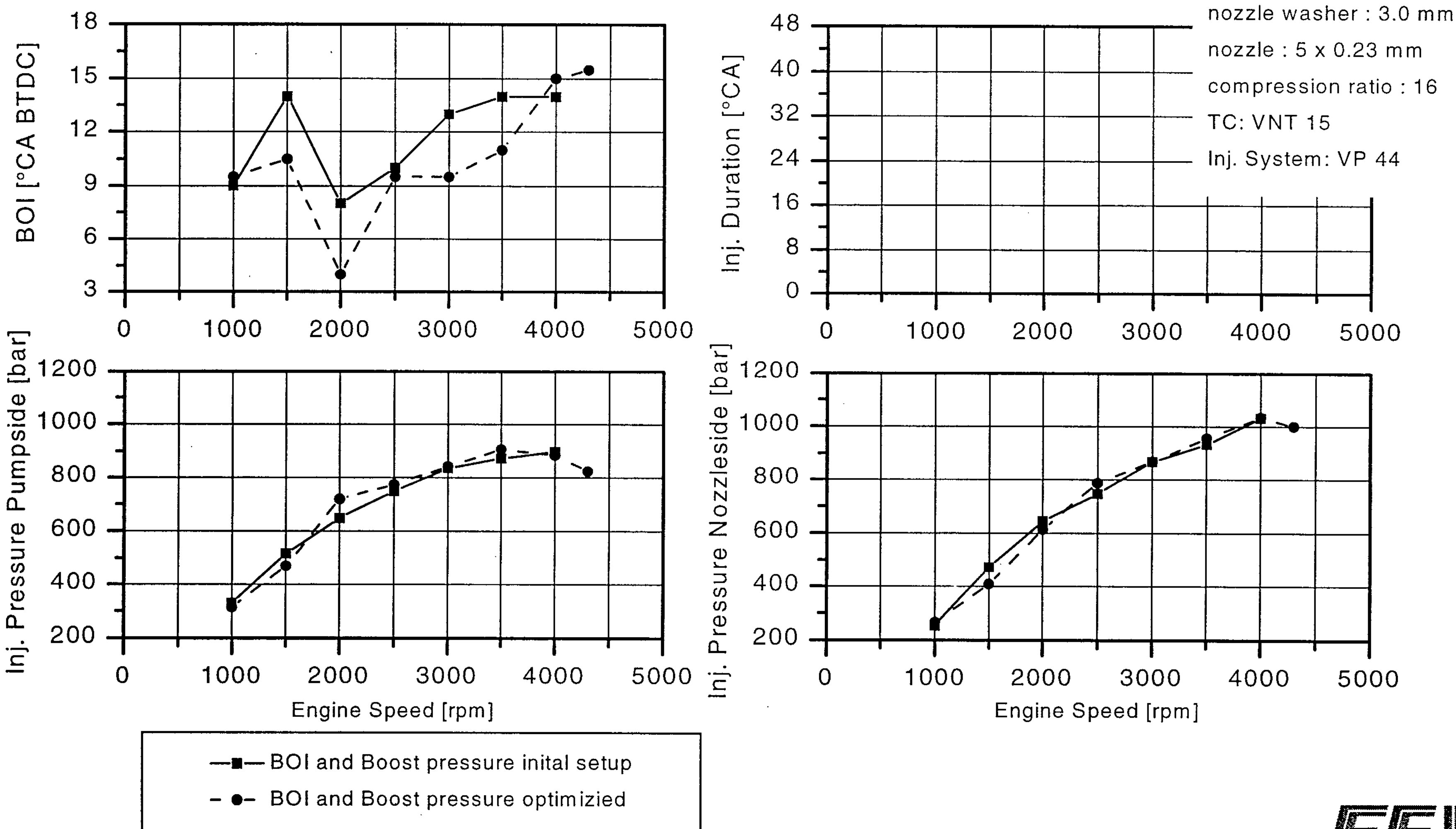
Figure 2.2.1 - 3
Influence of Injection Timing and Boost



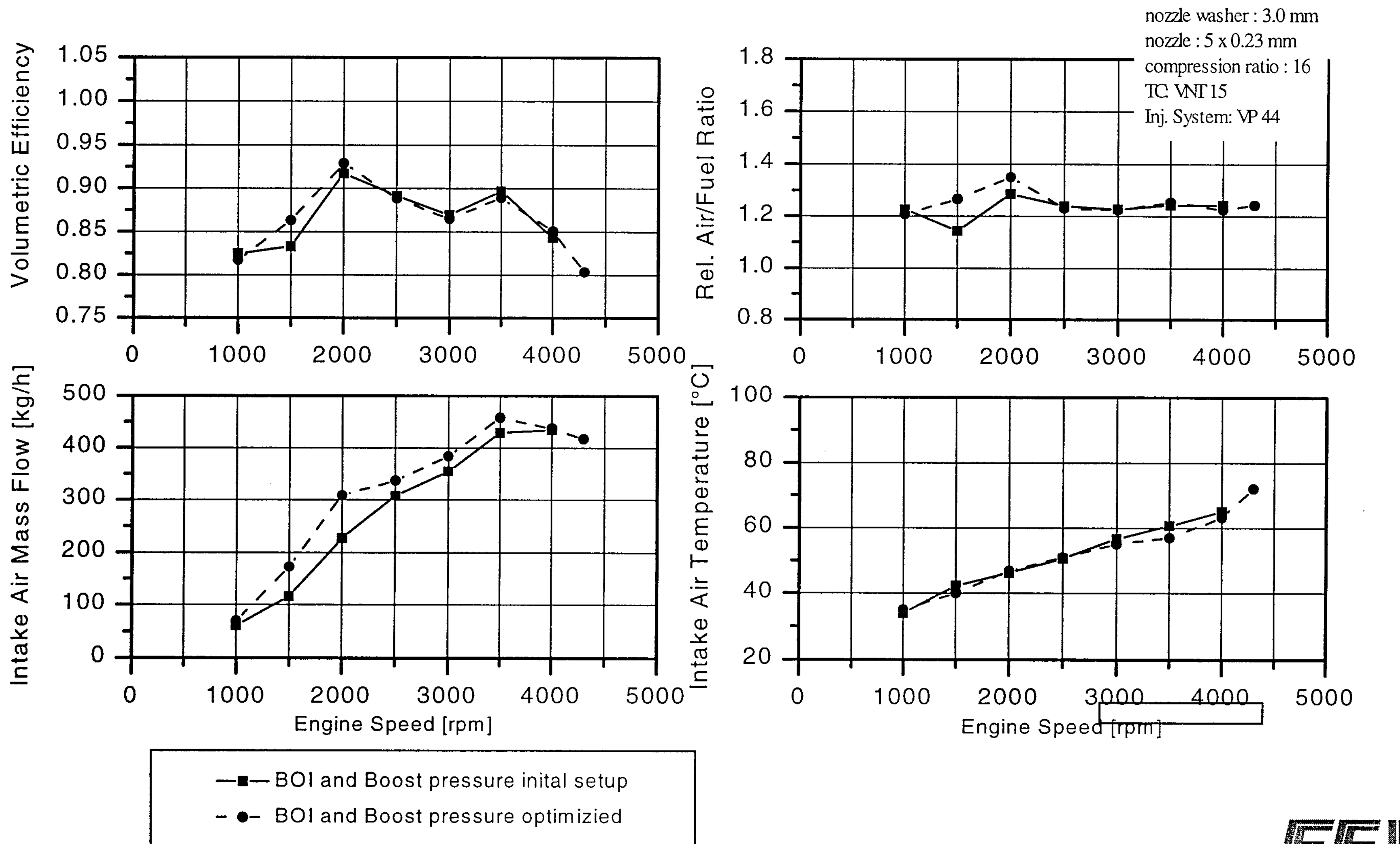
FEV Engine Technology

Figure 2.2.1 - 4
Influence of Injection Timing and Boost



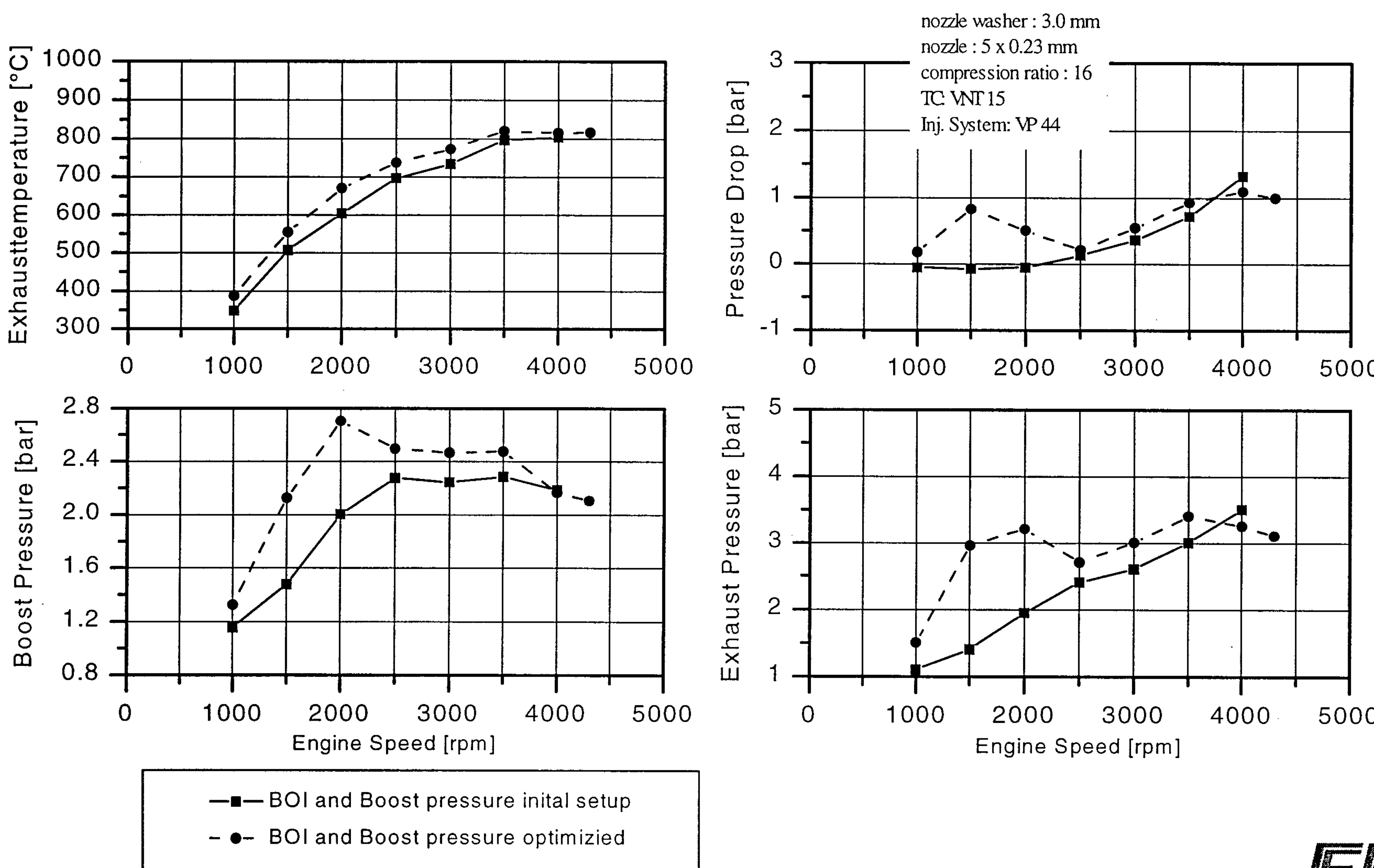
FEV
Engine Technology

Figure 2.2.1 - 5
Influence of Injection Timing and Boost



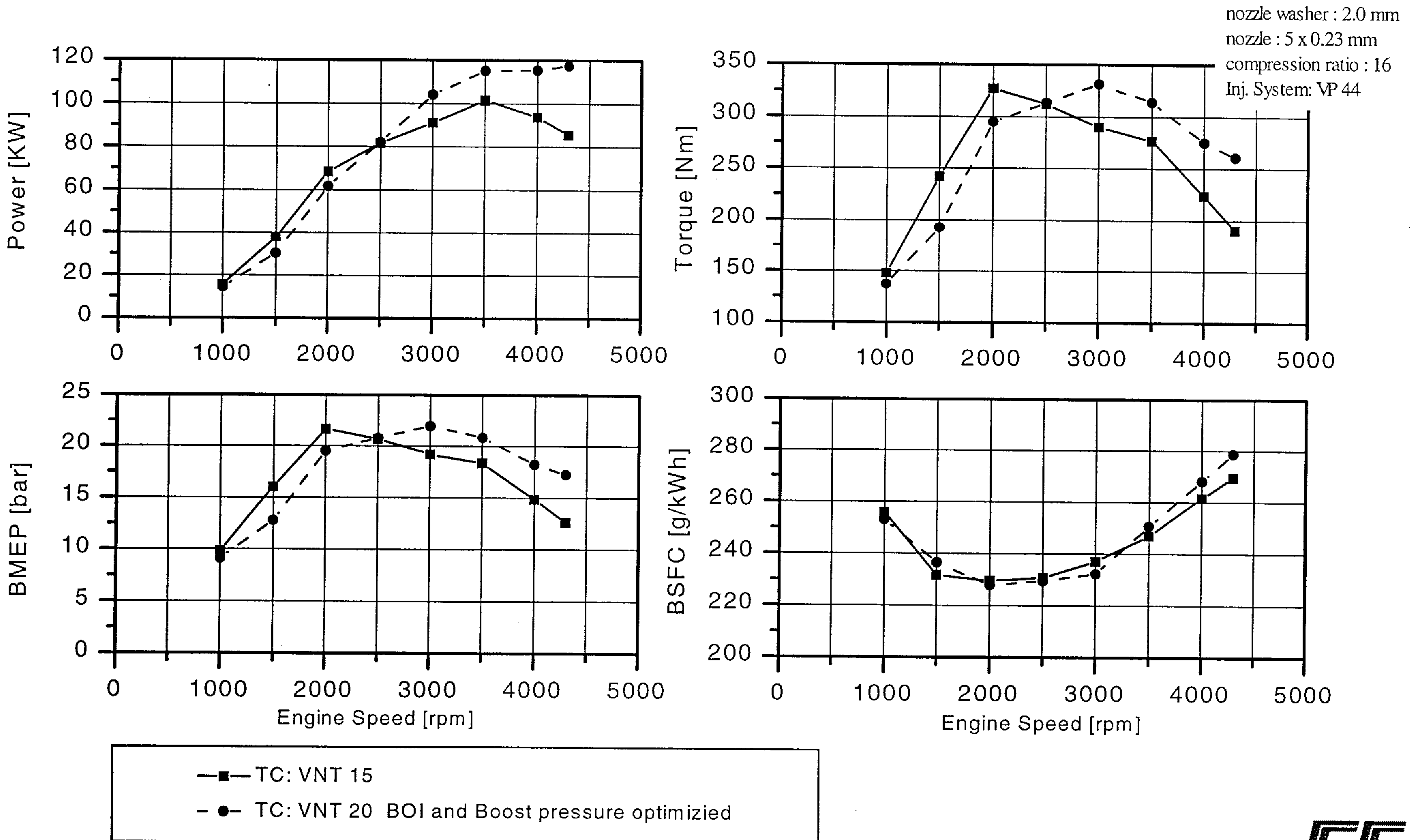
FEV Engine Technology

Figure 2.2.1 - 6
Influence of Injection Timing and Boost



FEV Engine Technology

Figure 2.2.1 - 7
Comparison of the VNT 15 versus the VNT 20



FEV Engine Technology

Figure 2.2.1 - 8
Comparison of the VNT 15 versus the VNT 20

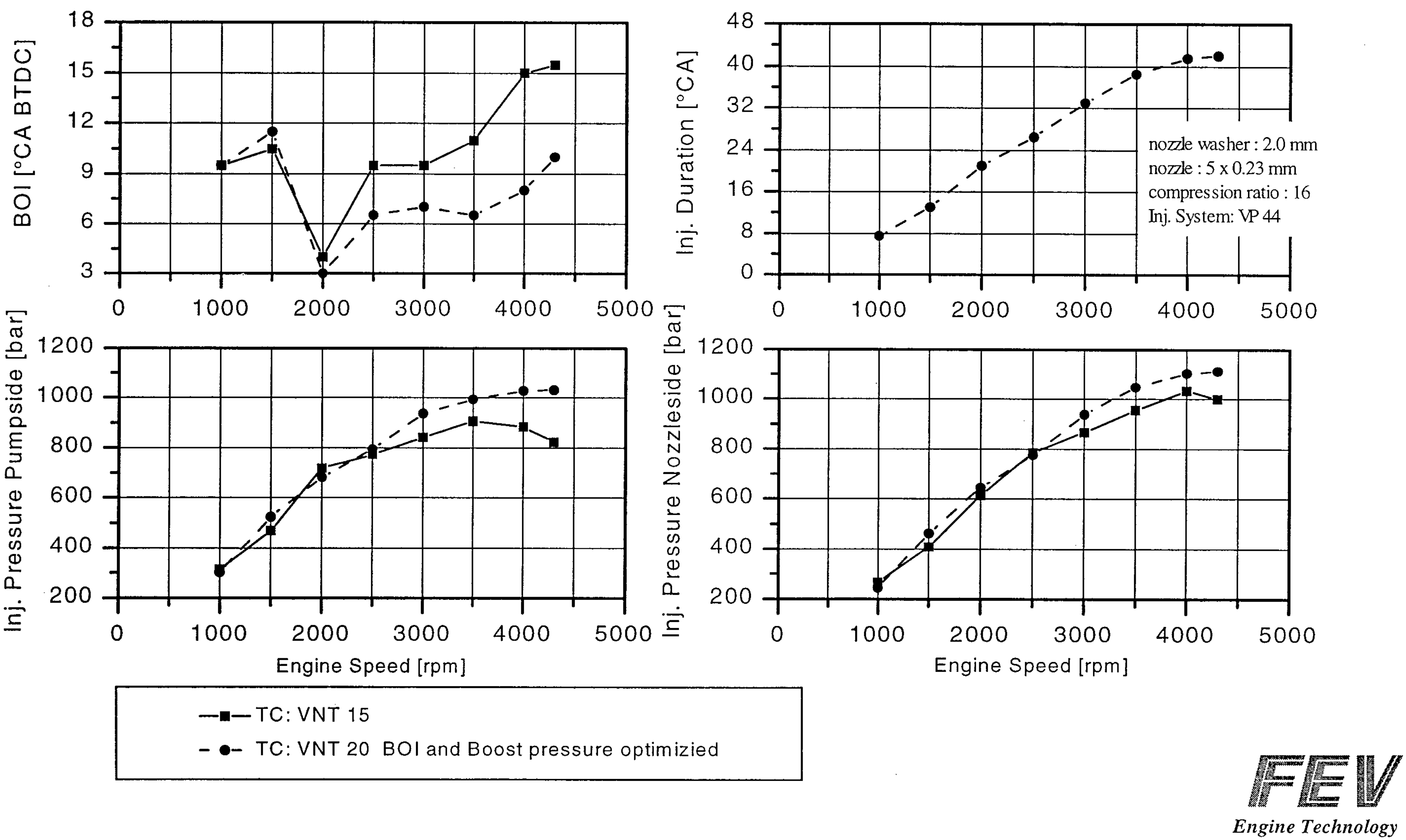
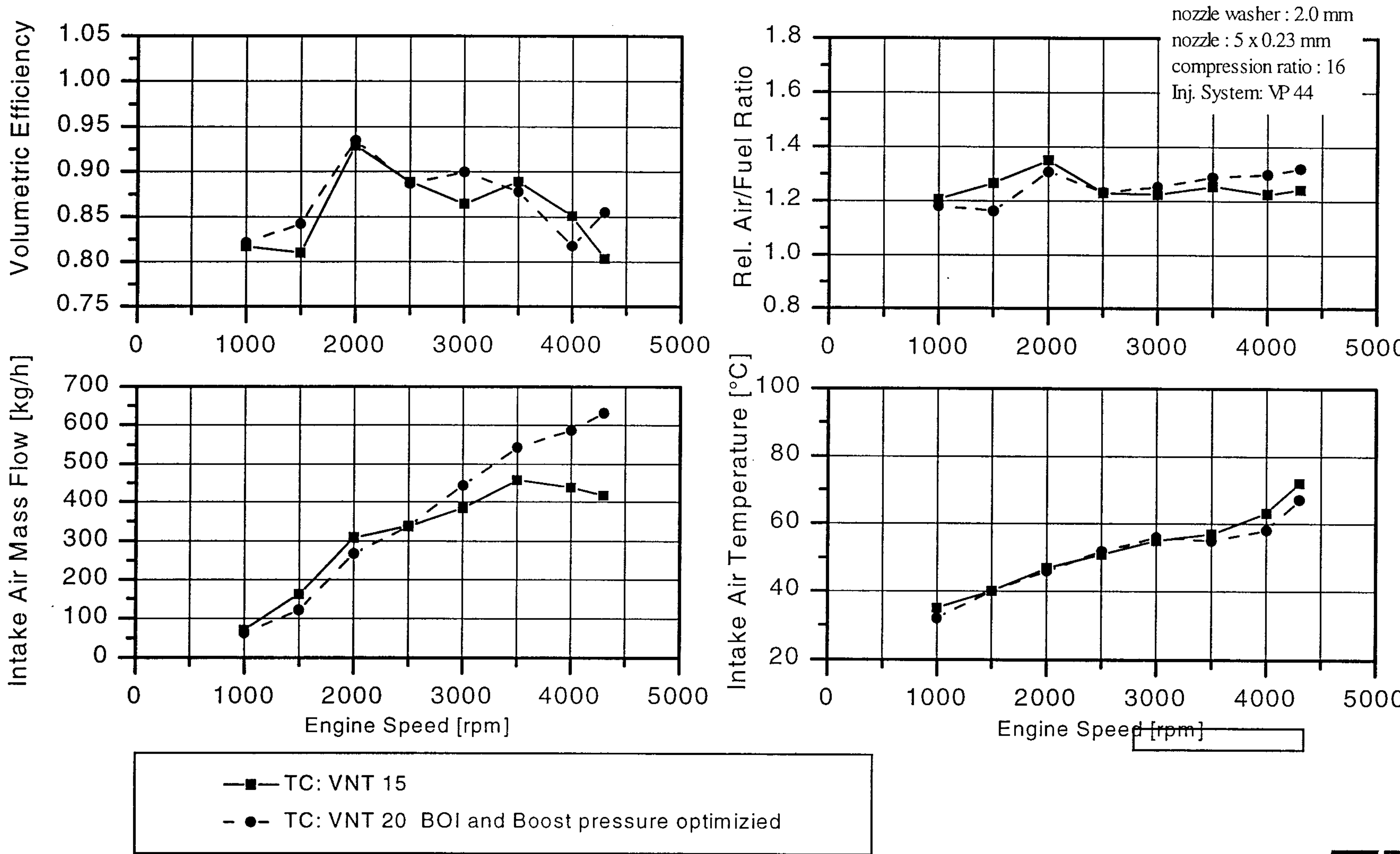
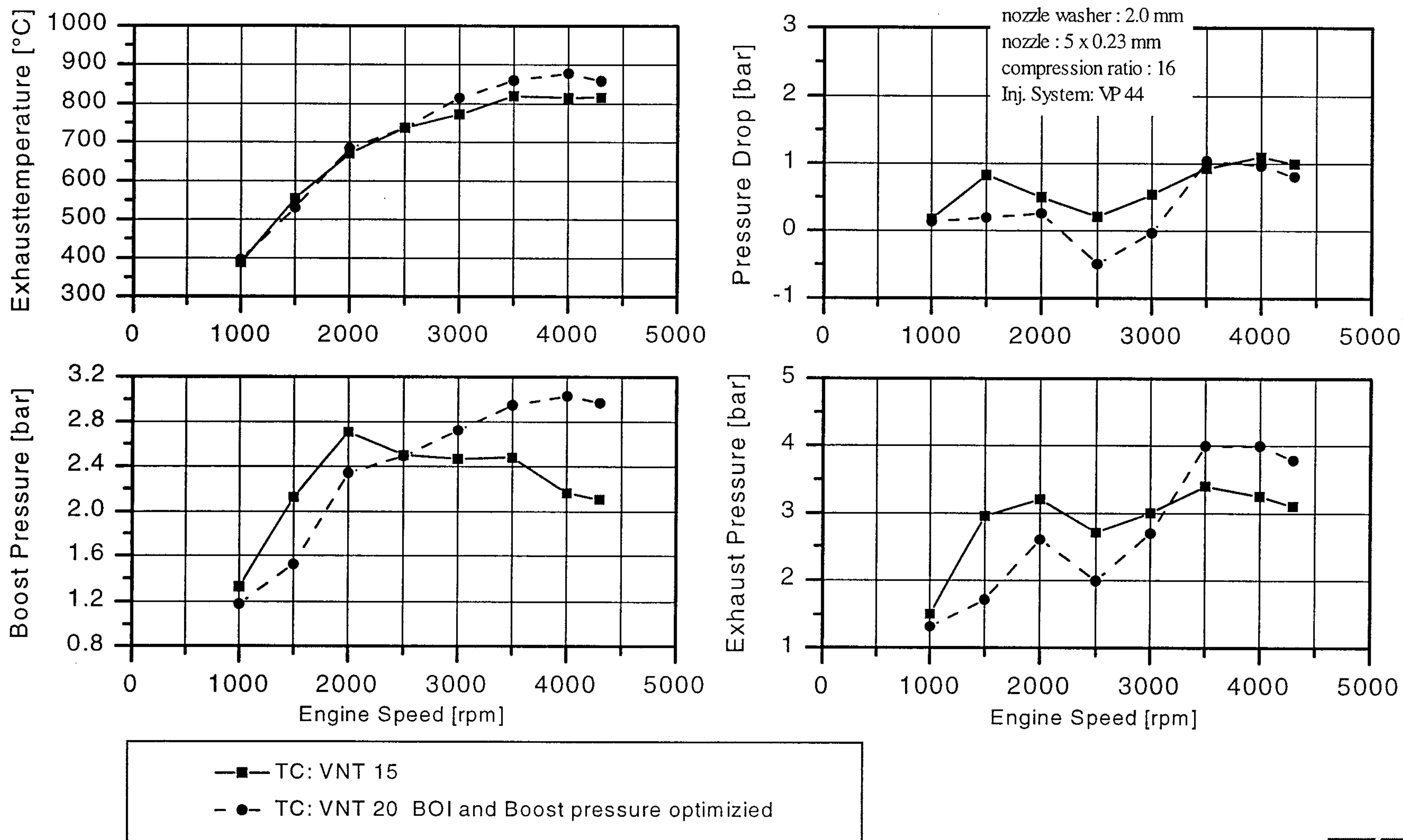


Figure 2.2.1 - 9
Comparison of the VNT 15 versus the VNT 20



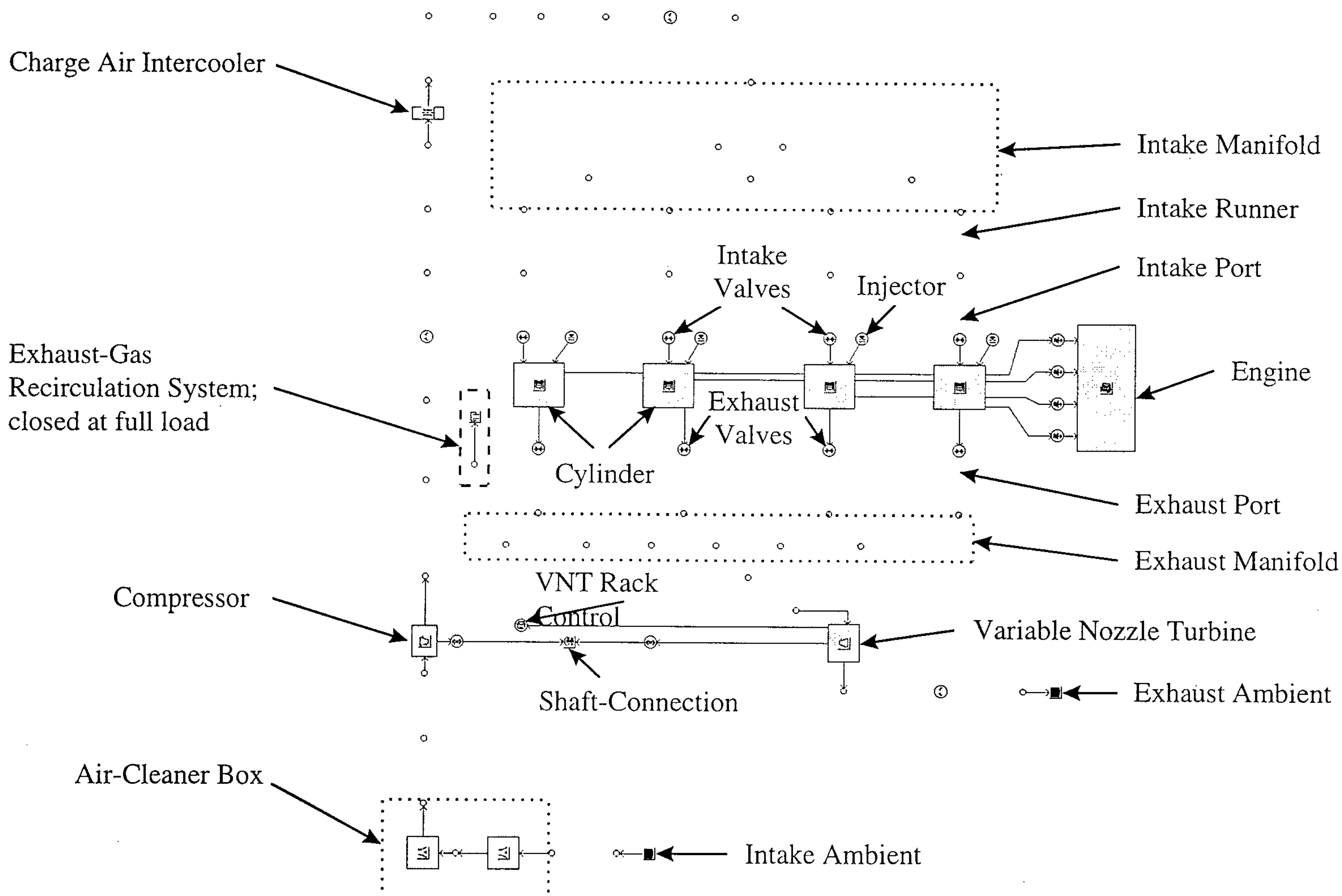
FEV Engine Technology

Figure 2.2.1 - 10
Comparison of the VNT 15 versus the VNT 20



FEV Engine Technology

Figure 2.2.2 - 1
Automotive Diesel Engine with 2 Valves and Variable Nozzle Turbocharger GTI-Calculation Model

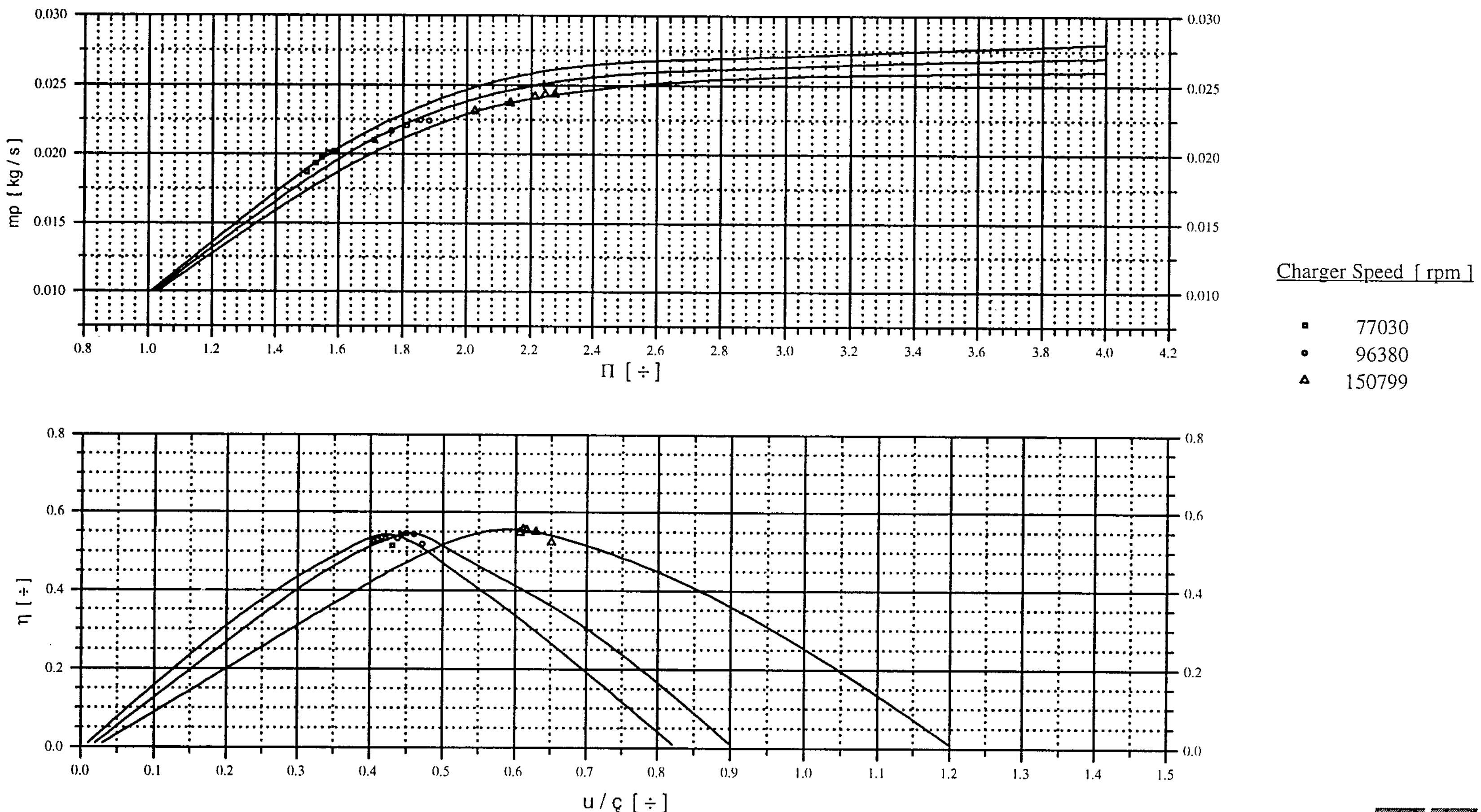


FEV Engine Technology

Figure 2.2.2 - 2
Maps for Variable Nozzle Turbine for Different Load Points

Full Closed

Turbine Wheel Diameter : 0.47 [mm]
Map Reference Temperature : 873.0 [° K]



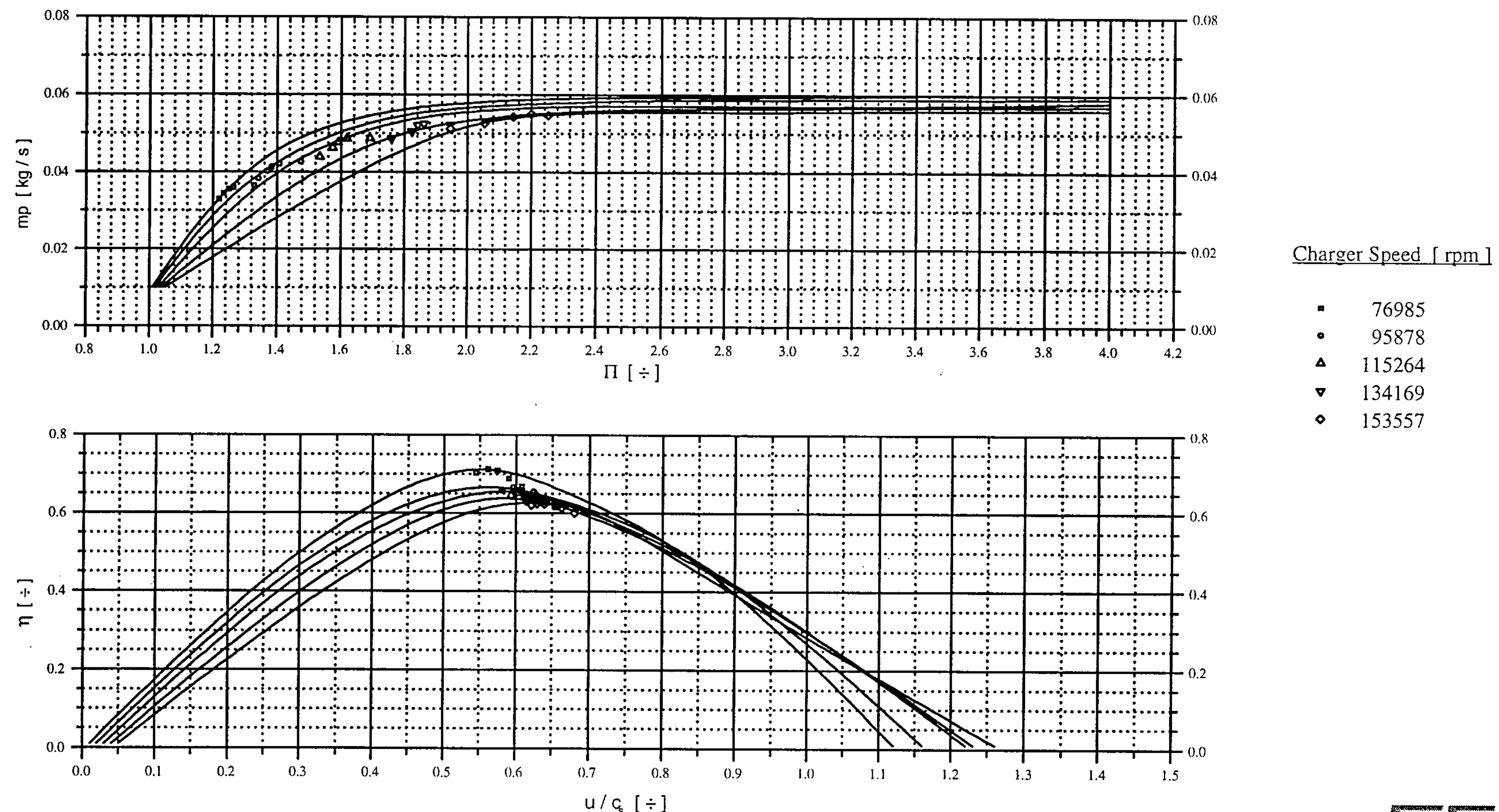
FEV Engine Technology

Figure 2.2.2 - 3

Maps for Variable Nozzle Turbine for Different Load Points

Half Open

Turbine Wheel Diameter : 0.47 [mm]
Map Reference Temperature : 873.0 [° K]

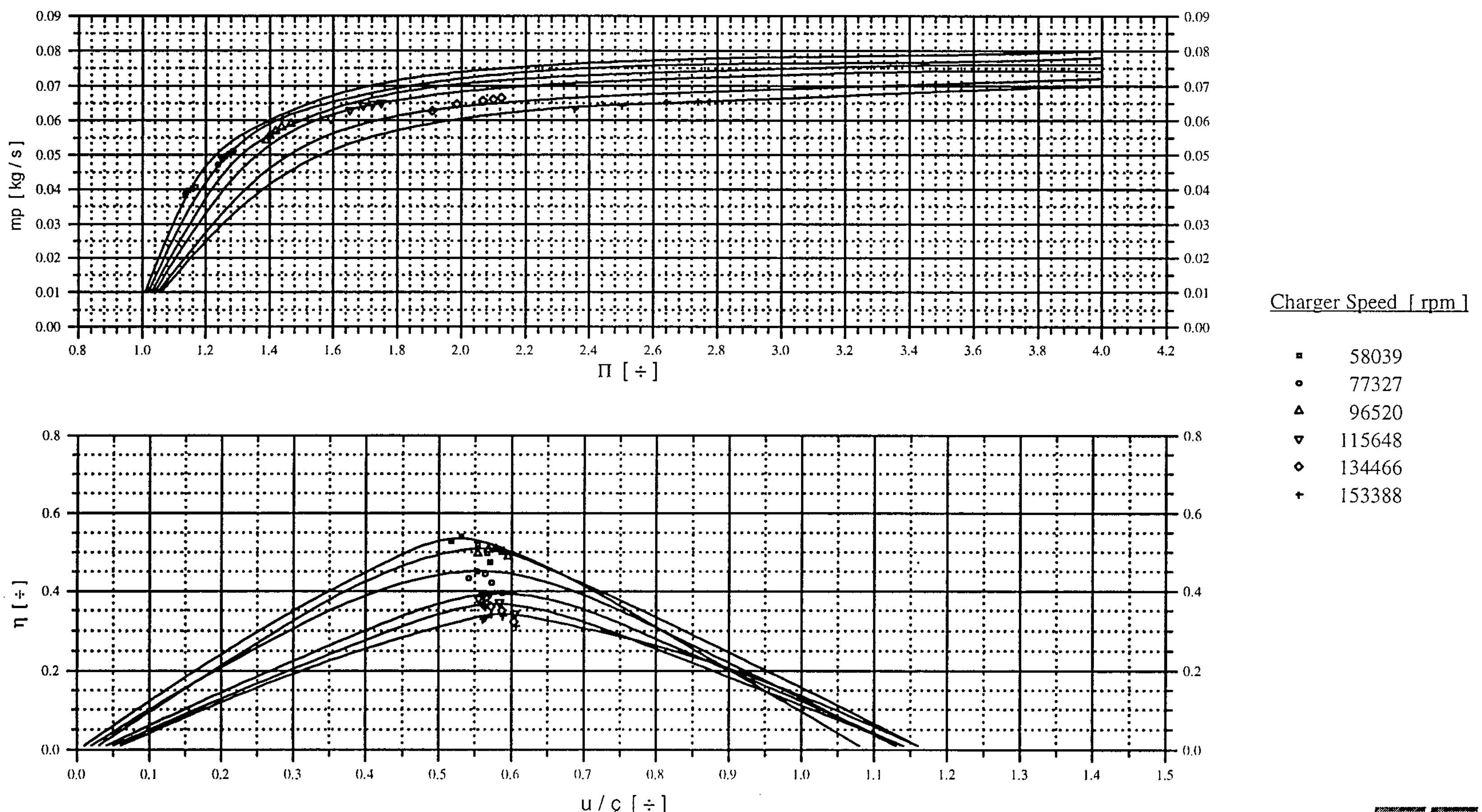


FEV Engine Technology

Figure 2.2.2 - 4
Maps for Variable Nozzle Turbine for Different Load Points

Full Open

Turbine Wheel Diameter : 0.47 [mm]
Map Reference Temperature : 873.0 [° K]



FEV
Engine Technology

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HEAVY FUEL INJECTOR

Project Manager: ***Engine Corporation of America***
CS-AR97A-03

The Engine Corporation of America (ECA) final report for this project is included as an attachment to this report. In this brief project, overall engine designs were produced for ECA's 1.0 liter opposed piston engine and the 0.5 liter half-engine variant. ECA fabricated plastic 1:1 scale models of all major components and furnished the components to FEV in support of the analytical work. ECA has provided FEV with all of the information, drawings, calculations and parts needed by FEV.

A final meeting between FEV and ECA is scheduled for October 1, 1997 to review fuel injection options for the engine. A summary of that meeting will be included in next quarter's report. ECA's fuel injection options assessment indicates that the Bosch Electronically Controlled Unit Injector and the Caterpillar/Navistar Hydraulic Electronic Unit Injection fuel system, the two highest technology injectors available today, are not acceptable for the Thermal Electric Compound Engine for a variety of reasons as discussed in the final report.

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	COMPLETE	MATCH FUNDS EXPENDED	DARPA FUNDS EXPENDED
1	1.0 Completion and submission of program plan	122,500	0	1	3/30/97			122,500
2	1.1 Overall Engine Design, 1.2 Engine Thermal Cycle Analysis,1.1 Coordination of Analytical Effort with FEV, 2.1 ECA Fuel Injector Design,2.2 Fuel Injector Options Assessment, 2.3 Coordinated Fuel Injection Review	122,500	245,000	2	6/30/97			
		245,000	245,000					122,500

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

HEAVY FUEL ENGINE (HFE) TEST PROGRAM

Project Manager: ***General Atomics Aeronautical Systems, Inc.***
CS-AR97B-01

Modification P00011 to MDA972-95-2-0011 allowed CALSTART to pursue a final agreement with GA-ASI. GA-ASI requested revisions, which were negotiated, and an agreement was sent for signature near the end of the quarter. It is anticipated that the first official report will be included in the next quarterly report. The draft milestone chart is included pending further revisions in GA-ASI agreement with CALSTART.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

APPENDIX

AMERIGON FINAL REPORT

CALSTART PROJECT HATCHERY ALAMEDA FINAL REPORT

NAVAL AIR STATION ALAMEDA CLUSTER PLANNING FINAL REPORT

RMSV ACTIVE DIFFERENTIAL FINAL REPORT

ROCKETDYNE
SAFE ELECTROMECHANICAL BATTERIES (EMB) FOR ELECTRIC AND HYBRID ELECTRIC VEHICLE FINAL REPORT

ENGINE CORPORATION OF AMERICA FINAL REPORT

COST REPORTING SUMMARY AND DETAIL

COMPLETED PROJECTS

CANCELED PROJECTS

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

AMERIGON FINAL REPORT

Final Report

DARPA/CALSTART Electric Vehicle Chassis Agile Manufacturing Program

August 1, 1997

Amerigon Incorporated
5462 Irwindale Avenue
Irwindale, CA 91706

AMERIGON

Leader In Advanced Automotive Technologies

November 6, 1997

Linda Wasley
3601 Empire Avenue
Burbank, CA

Dear Linda,

Per conversation with Chetan:

The over $2.2 million that's quoted as matched fund in the DARPA report was premature. After accounting assessment the correct figure is over $4 million.

Thank you very much.

Sincerely,

Robert Marcellini
General Manager
Electric Vehicles

Cc: Chetan Maini

TABLE OF CONTENTS

1.0 INTRODUCTION:

1.1 Description of Effort

CALSTART's Running Chassis Program is an effort to develop and bring into production electric vehicles based on a light-weight, low cost, durable aluminum space frame construction technology. The ultimate aim of the program is to develop a new electric vehicle that can be produced for low costs at relatively low volume.

1.2 Background

Phase 1 of the Running Chassis Program was completed in February of 1994 with the roll-out of the first prototype running chassis. The goal of Phase 1 was to demonstrate that extruded aluminum components could be formed and bonded with adhesives into a working prototype vehicle.

Phase 2 of the Running Chassis Program was launched in the second quarter of 1994 with $875,000 of funding from the California Energy Commission (CEC) and the South Coast Air Quality Management District (SCAQMD). The goal of Phase 2 was to test and evaluate the performance of the first running chassis prototype. The product of this Phase was a vehicle with improve components, a more stable frame, improved placement of the battery compartments and increased effectiveness of the adhesive bonding process.

1.3 Project Goals

The space frame utilizes advanced aerospace technology that requires much lower capital costs than traditional auto conversation techniques. This new technology also allows the production of multiple vehicle types on the same agile manufacturing line. By developing a process that requires lower capital costs and allows different vehicle type to be produced on the same manufacturing line, relatively small numbers of vehicles can be built at a low cost per vehicle. As a result, this new advance provides the breakthrough in technology needed to overcome one of the major barriers to the successful also provides the light-weight and durable space frame characteristics required by electric vehicles.
Advantages of the running chassis are:

- can be built on the same agile production line thereby increasingly the total volume of vehicles produced,
- reduce the amount of capital required for vehicle produced,
- lower the final cost of both civilian and military vehicles, and
- accelerate the successful introduction of electric vehicle technology.

Date	11/20/95 Program	DARPA $	Match $
11/14/95	Initial Payment	200	460
12/31/95	Completion of the following: 1) Breadboard Design of productionized drive train; 2) EV Running Chassis; 3) BEV with steel space frame & 4) Installation of advanced components in 1st EV4	175	200
3/31/96	Fabricate EV4 and BEV Prototype parts; Fabricate parts of attachment of body, interior, frame; Revise design packages for veh. system and package; Complete build of EV4.	125	0
6/30/96	Complete EV4 and BEV Vehicle Tests. Revise tools for EV4 and BEV.	150	20
9/30/96	Build 2 advanced BEVs w/welded and bonded chassis; Complete design package for productionized power and control systems for BEV; Complete and test five productionized power and control systems for BEV.	50	0
12/31/96	Final Report: Complete	0	40
	Total	700	720

Table 1

The key components of an electric vehicle include the powertrain, charger and battery management. However, very few systems are currently available that integrate the charger, motor controller, dc-dc converter and energy management system that are low cost. The second goal of this program was to develop and test 5 low cost Integrated Power System (IPS) that could be used for small electric vehicle.

To achieve these goals, Amerigon has advanced the state of Running Chassis technology for two different vehicle types. The first is a 4-passanger sedan targeted for industrialized countries, known as the EV4. The second is a Basic Electric Vehicle (BEV) suitable for export to developing country markets. The specifications for the EV4 and BEV can be found in Appendix 6. Table 1 summarizes the original deliverables and payments.

2.0 ACCOMPLISHMENTS

Significant advancements were made in the Running Chassis technology as well as in the development of low cost drivetrain. A summary to these developments are listed in Table 2

In the development of the aluminum chassis extensive work was done on the bonding of major joints in the running chassis. By building chassis of 2 different sizes it is easy to see that the technology is scaleable and has numerous applications. Also having built aluminum and steel running chassis for the BEV, we were able to determine the relative advantages and disadvantages of each type of chassis, by conducting numerous tests. This information is summarized in Appendix 5. Also in the development of the running chassis, detail Finite Element Analysis was performed and the results of the actual tests were used to verify the BEV Finite Element model. By updating the model we were then better able to predict how the chassis would behave under different load conditions. FEA results for the EV4 are summarized in Appendix 10

The BEV also completed 4 post shaker testing that simulated over 200,000 kilometers of city driving, with no failures to the vehicles chassis or body system. A key area that was verified was the attachment methodology of the plastic body panels to the steel space frame. This information was key in making changes to the running chassis. Some of the suspension and drivetrain component designs were modified based on these tests.

Amerigon has also developed a high quality vacuum forming process to manufacture low cost plastic body panels. The panels for the BEV are made from co-extruded ABS that gives a panel a glossy finish and does not required to be painted. These high-impact plastic panels are less complex and less expensive to manufacture in limited quantities that existing methods. This process is ideal for low volume manufacturing, as the vacuum forming capital costs are low and a painting plant is not required.
The EV4 vehicle that Amerigon developed uses composite panels manufactured using the Resin Transfer Process (RTM). This again is a fairly low cost manufacturing method for body panels. A lot of work was done in developing suitable attachment schemes to fix the body panels to the space frame. Tolerances, assembly issues, temperature considerations were important things that were addressed in order to arrive with designs for body panel attachments.

The design of the Integrated Power System (IPS) involved many advanced developments. In particular, the entire productionized power system was value analyzed to the component level. The specifications for the system were finalized and the unit costs at various production volumes was calculated and then further optimized The IPS consist of a motor controller, charger, dc-dc converter and energy management system (EMS), that are packaged together. The charger is light weight and low cost and has the dc-dc converter integrated into the same board. The energy management system is microprocessor based and in addition to monitoring the batteries and providing accurate state of charge display, it also controls the charging algorithm. This enables the charging of the batteries to be optimized. In addition to making the IPS smaller and lighter, the most significant work done was the decrease in the system cost. The system has approximately 50% fewer components, is 60% cheaper to manufacture and has improved performance over the previous systems. There are also significant improvement in the reliability of the system by designing in redundant circuits and having the entire IPS sealed and cooled by free convection. Pictures of the IPS are in Appendix 4

.

TASK	NAME	TECHNICAL INNOVATION AND ADVANCES
1	Baseline testing of Running Chassis	• Create important baseline measures of performance in initial and subsequent prototypes.
2	Develop Key Components	• Development of advanced prototypes of power systems, climate control seats and energy management systems.
3	Fabricate 2nd Generation Running Chassis	• Development of low-cost and repeatable methods of assembling extruded aluminum running chassis using both welded and bonded joints suitable for cost-effective low-volume manufacture.
4	Plastic Body and Interior Panel Development for Space Vehicle	• Concurrent engineering methods for subsystems complex vehicle structures. • Design of low cost recyclable panels with near Class A finish that eliminate the need for painting.
5	Vehicle System and Package Design	• Accurate modeling of plastic panel / space frame members, that exhibit low vibration & noise. • Concurrent engineering methods of integrating complex vehicle subsystems.
6	Attachment of Body, Interior and Frame	• Low stress, leak-proof attachment of panels to frame members, that exhibit low vibration & noise. • Low cost attachment and joint designs that forgive tolerance stack up and thermal expansion mismatched.
7	Productionized powertrain system design for BEV	• Integration of micro-processing and control functions from a battery monitory, battery charger and energy management system • Design of low-cost package for high-quality manufacture in initial low-volumes • Improvements in battery cycle life and range as a result of proper control of charge and discharge
8	Vehicle Design Validation (DV) build and test	• Verification of technical advances in body panels, vehicle design, assembly and system integration • Over 200,000 km of 4 post shaker tests successfully completed • BEV's driven over 20,000 kms. • Quantitative measures of performance gains achievable in EVs with plastic panel / space frame / EMS system • Durability, stability, and environmental capability measures of EV4 and BEV • Comparison of steel verses aluminum space frame • BEV successfully completed side impact testing • BEV is homologated for sale in India
9	Design and tooling revision	• Solutions to defects associated with state-of-the-art design, joining and attachment processes.

TABLE 2

3.0 DEVIATIONS TO PLAN

All objectives as set per the modified agreement 002 (see Appendix 1), were completed. This included the design and fabrication and testing of 1 EV4 and BEV, construction of 4 Aluminum BEV running chassis and the design, testing and fabrication of 5 advanced BEV drivetrains. Pictures of these can be seen in Appendix 2-4. The modified deliverables are stated in Table 3.

The modifications made have the same goal of advancing the running chassis technology and achieving important innovations. However, since the original proposal, Amerigon had successfully won $9 million in orders from commercial customers for complete "wheels up" electric vehicles base on space frames.

The modifications redirected our development activities towards the design and fabrication of two vehicle types sought by existing and potential customers. The project team undertook difficult technological challenges and achieved several important innovations and advances in the process of designing and fabricating these vehicles. This modification will also help the early commercialization of electric vehicles based on the running chassis concept

4.0 PROJECTIONS

The project was originally to be completed by 12/31/96, but was actually completed on 6/30/97, a 6 month delay. Reasons for this delay were both technical as well as business related.

At the technical end we had significant delays on the body tooling for both the EV4 and the BEV. The concepts used in the body panels were new and required extra time to debug. The IPS development involved more integration of the electronics that we originally envisioned. In addition we spent significant amount of time on vehicle and sub-system testing and made suitable design changes based on those test results.

Amerigon has also had delays and difficulty resolving the business issues. While we have designed and built 5 BEV prototypes and performed substantial testing on the prototypes, we have encountered substantial difficulty in our dealings with the Indian Government, our local partner in India and our financial investors. These difficulties are centered around issues such as the technology license rights, management and control and other business issues.

Although the program was delayed by 6 months, the end deliverables are more advanced then initially proposed. Significant testing of the vehicles have been completed to verify the designs. Also the IPS and complete BEV design is closer towards production. This involved fabricating many production ready tooling to made body panels and chassis parts.

Date	11/20/95 Program	DARPA $	Match $	Modified Program	DARPA $	Match $
11/14/95	Initial Payment	200	460	Initial Payment	200	460
12/31/95	Completion of the following: 1) Breadboard Design of productionized drive train; 2) EV Running Chassis; 3) BEV with steel space frame & 4) Installation of advanced components in 1st EV4	175	200	Completion of the following: 1) Breadboard Design of productionized drive train; 2) EV Running Chassis; 3) BEV with steel space frame & 4) Installation of advanced components in 1st EV4	175	200
3/31/96	Fabricate EV4 and BEV Prototype parts; Fabricate parts of attachment of body, interior, frame; Revise design packages for veh. system and package; Complete build of EV4.	125	0	Fabricate EV4 and BEV Prototype parts; Fabricate parts of attachment of body, interior, frame; Revise design packages for veh. system and package.	125	0
6/30/96	Complete EV4 and BEV Vehicle Tests. Revise tools for EV4 and BEV.	150	20	Complete all BEV Vehicle Tests. Revise tools for EV4 and BEV.	40	15
9/30/96	Build 2 advanced BEVs w/welded and bonded chassis; Complete design package for productionized power and control systems for BEV; Complete and test five productionized power and control systems for BEV.	50	0	Complete all BEV vehicle tests. Revise tools for EV4 and BEV.	0	0
12/31/96	Final Report: Complete	0	40	Complete and begin testing of first productionized drive train.	0	0
3/30/97	None	0	0	Complete Finite Element (FEA) and design of running chassis BEV; 75% completion of first aluminum chassis.	0	0
6/30/97	None	0	0	Complete build and testing of all 4 aluminum BEVs - all w/0 body panels (2 with welded frames; 2 with welded and bonded - two BEVs should be advanced Bev's); Complete build and test of 5 productionized drive trains. Complete comparative analysis of chassis designs and structure. Complete final report.	160	45
8/1/97						
	TOTAL	700	720	TOTAL	700	720

Table 3 (Modifications to Original Statement of Work)

5.0 FINANCIALS

The total cost to complete the grant deliverables is substantially higher than that indicated in the original statement of work. Amerigon has independently funded these cost overruns. The grant had a budget of $1.42 million that included a match payment from Amerigon for $720,000. From conception of this project, Amerigon has spent over $2.2 million and doubled its match payment. All this extra money went towards decreasing the cost of the IPS and taking the vehicle design closer towards production.

6.0 CONCLUSION

A significant amount of work has been done to advance the running chassis technology. Two different platforms of chassis were designed, fabricated and tested. Also 5 low cost IPS's were designed, fabricated and tested. In addition, a comparison of the Steel to Aluminum chassis was also conducted to see the relative advantages of an aluminum space frame over a steel space frame. The pictures of the deliverables, specifications and test results in the appendices further detail the work done over the last 1 ½ years at Amerigon.

The EV4 chassis that was fabricated was one out 48 such frames made at the NAS. There are currently 40 of such vehicles that use the EV4 running chassis that are currently operating in Korea for Samsung Corporation. In addition there are currently 8 additional BEV's operating and 18 kits that are based off the BEV running chassis. The BEV, called the REVA, received a preliminary launch in India, of which press releases can be seen in Appendix 13.

We are currently working to find a Strategic partner in India to manufacture the REVA. This would lead in a joint venture to manufacture low cost electric vehicles. A significant portion of the components in the initial years will be exported from the US and would include the Integrated Power System (IPS).

It is important to realize that Amerigon had two large EV projects for which ARPA provided assistance. By using the ARPA funding to leverage on our current developments, we were able to make significant development in advancing the running chassis technology and bringing EV's closer commercialization.

Appendix 1: Modification Agreement

CALSTART

MODIFICATION 002

Agreement between
CALSTART
and
AMERIGON
Dated: May 30, 1995

Modification 002 to the Agreement dated May 30, 1995 and the Modification 001 signed 11/20/95 replaces the budget/milestone exhibit labeled Exhibit A.

The term of this contract shall be through 12/31/97.

ARTICLE I
GENERAL RESPONSIBILITIES

Section 1.2 Project Obligations: This section is amended to read as follows:

Section 1.2 Project Obligations.
The Participant shall carry out the Project and shall incur obligations against and make disbursements of Project funds only in conformity with the latest budget for the Project, which may be revised in writing by CALSTART and Participant. The Project Budget, including related time frames, milestones and deliverables for the Project, is attached hereto as Revised Exhibit A. The Statement of Work for the Participant is set out in Exhibit B. Failure to perform the work as described in either Exhibit A or B may result in termination of the contract. Participant will be permitted to seek reimbursement from CALSTART for costs expended, subject to provisions of the Revised Program Participant Manual and DARPA funding up to **$700,000.00** in approved funds from 1994. Invoices shall be submitted in accordance with the Budget/Schedule/Milestones set out in Exhibit A using the form provided as Exhibit C. The Participant shall bear all costs and expenses that are not accepted for payment by DARPA, unless CALSTART, in conjunction with DARPA determines otherwise.

All other references and sections of the original contract remain in force with full effect.

Signed:

John Boesel 8/7/97
John Boesel Date
Executive Vice President

8/7/97
Date

Exhibit A - Modification 2

DARPA MDA972-95-2-0011

AMERIGON RUNNING CHASSIS II PROGRAM

Date	11/20/95 Program	DARPA $	Match $	Revised Program (DARPA Approved 6/6/97)	DARPA $	Match $
11/14/95	Initial Payment	200	460	Initial Payment	200	460
12/31/95	Completion of the following: 1) Breadboard Design of productionized drive train; 2) EV Running Chassis ; 3) BEV with steel space frame & 4) Installation of advanced components in 1st EV4	175	200	Completion of the following: 1) Breadboard Design of productionized drive train; 2) EV Running Chassis ; 3) BEV with steel space frame & 4) Installation of advanced components in 1st EV4	175	200
3/31/95	Fabricate EV4 and BEV Prototype parts; Fabricate parts for attachment of body, interior, frame; Revise design packages for veh. system and package; Complete build of EV4.	125	0	Fabricate EV4 and BEV Prototype parts; Fabricate parts for attachment of body, interior, frame; Revise design packages for veh. system and package.	125	0
6/30/96	Complete EV4 and BEV Vehicle Tests. Revise tools for EV4 and BEV.	150	20	Complete all BEV vehicle tests. Revise tools for EV4 and BEV.	40	15
9/30/96	Build 2 advanced BEVs w/welded and bonded chassis; Complete design package for productionized power and control systems for BEV; Complete and test five productionized power and control systems for BEV.	50	0	Complete build of EV4. Complete EV4 vehicle tests.	0	0
12/31/96	Final Report: Complete	0	40	Complete and begin testing of first productionized drive train.	0	0
3/30/97	None	0	0	Complete Finite Element Analysis (FEA) and design of running chassis BEV; 75% completion of first aluminum chassis.	0	0
6/30/97	None	0	0	Complete build and testing of all 4 aluminum BEVs - all w/o body panels (2 with welded frames; 2 with welded and bonded – two BEVs should be advanced BEV's); Complete build and test of 5 productionized drive trains. Complete comparative analysis of chassis designs and structure. Complete final report.	160	45
				TOTAL	700	720

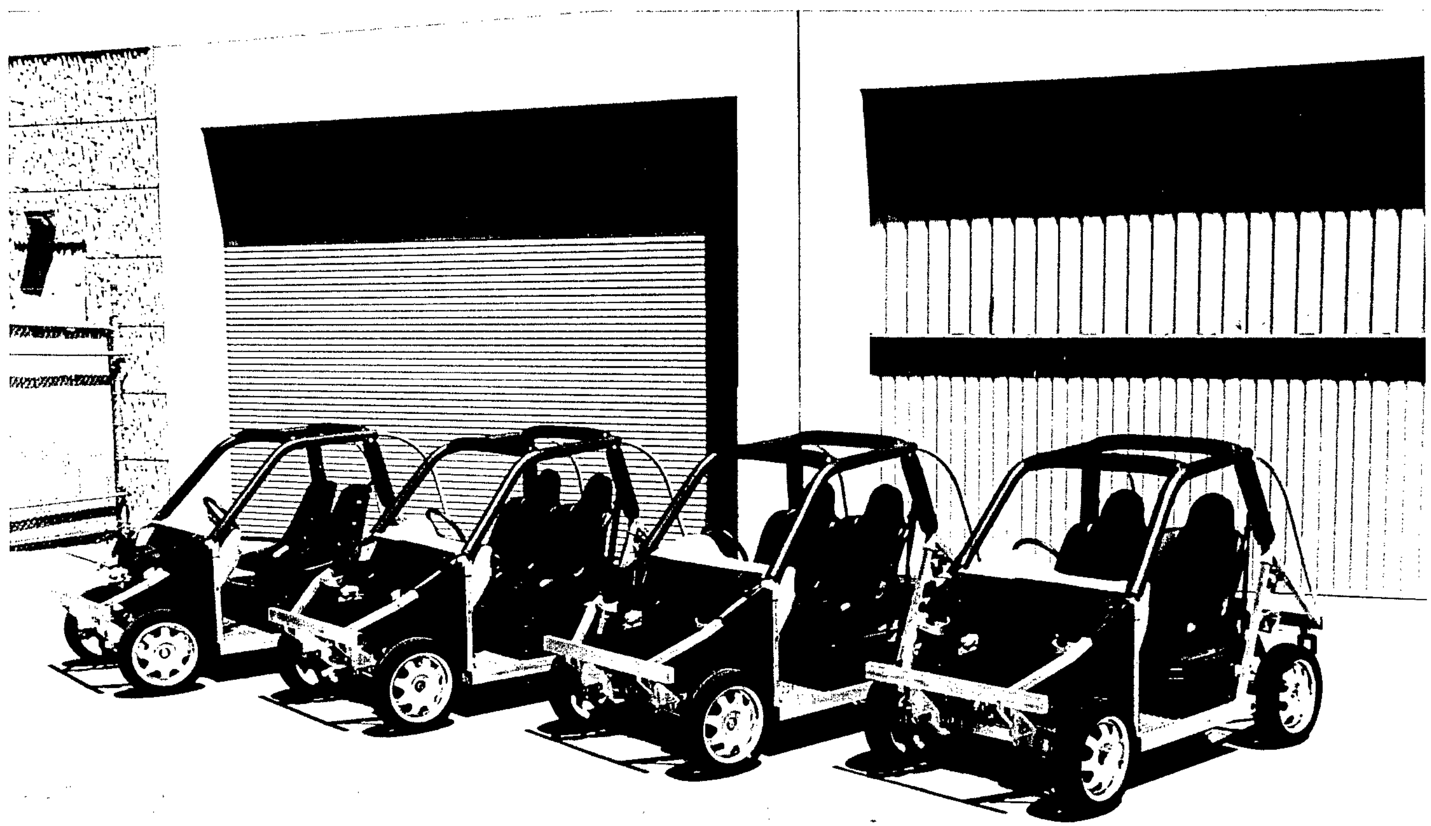
Appendix 2: Photos of BEV and EV4

Completed BEV (REVA)

EV4 Electric Vehicle

Appendix 3: Photos of Aluminum BEV Running Chassis

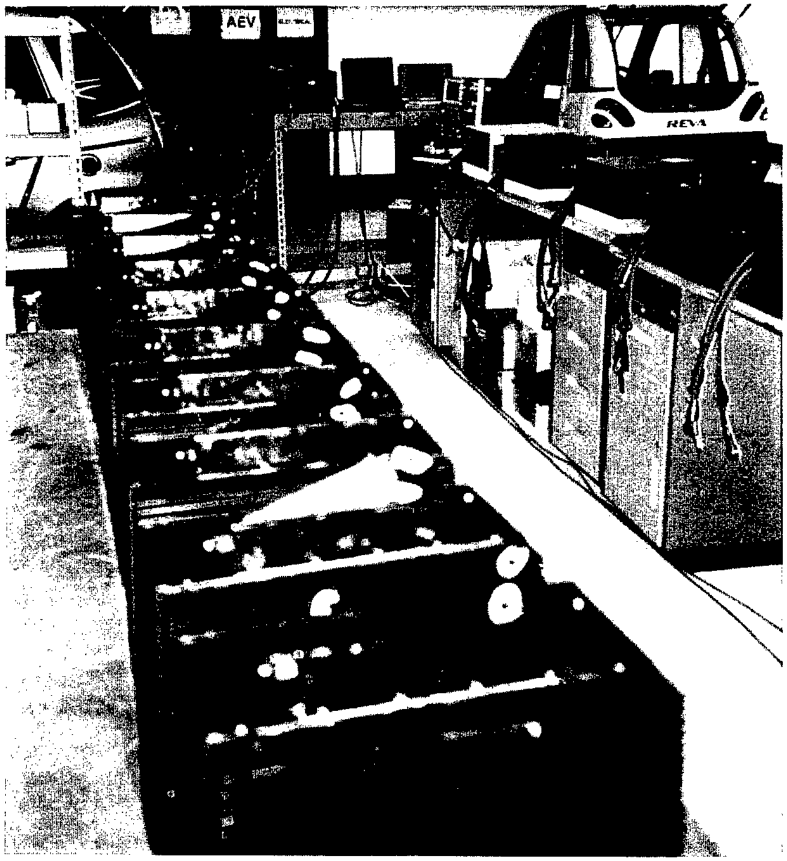
Aluminum BEV Running Chassis



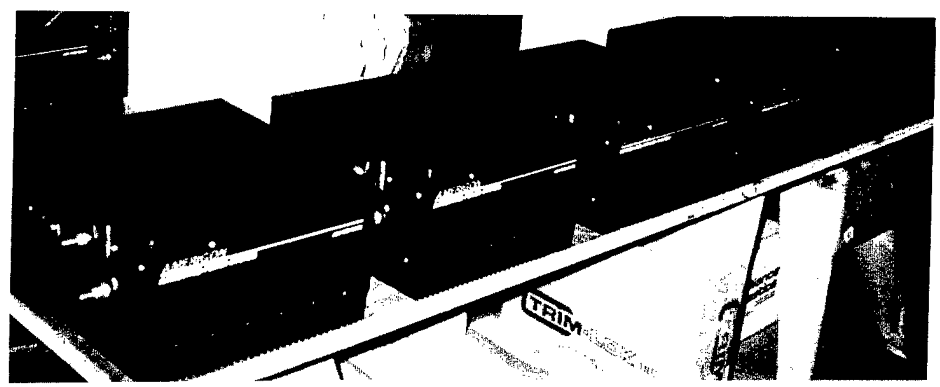
Aluminum BEV Running Chassis

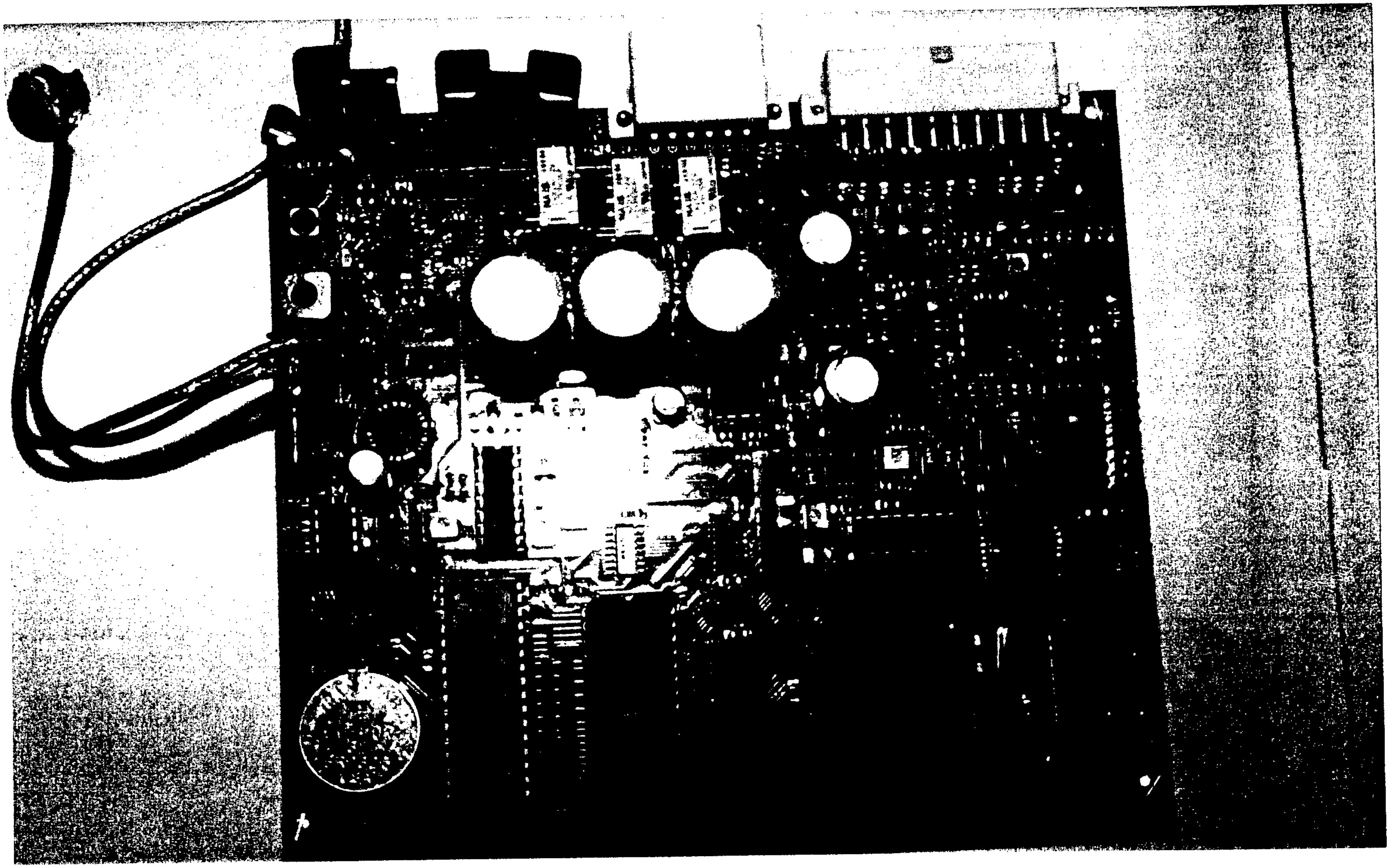
Appendix 4: Photos of Integrated Power System and Energy Management System

Integrated Power System

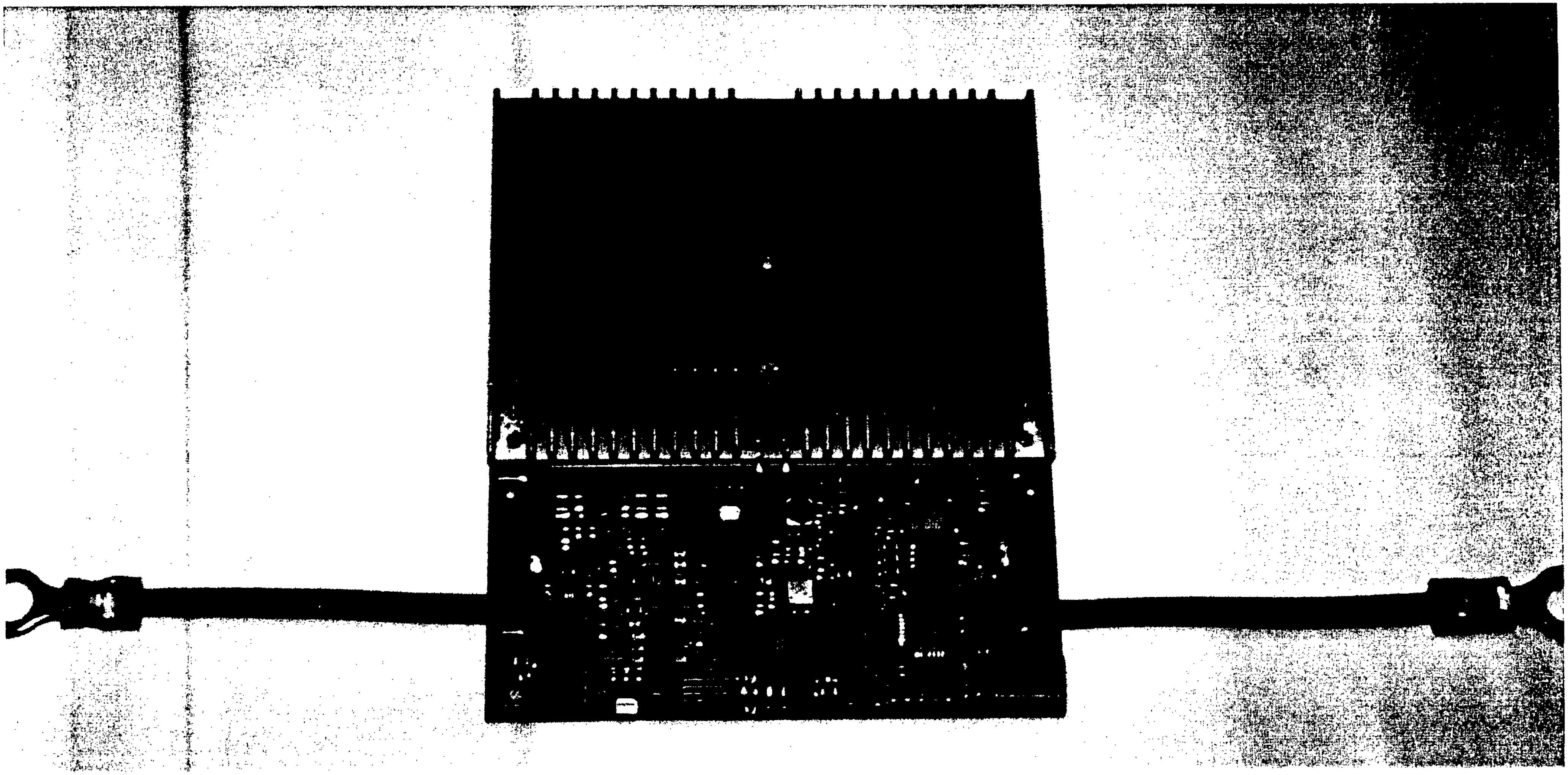


Integrated Power System





EMS Main Module



Energy Management System (EMS) Battery Module

Appendix 5: Performance Report on BEV Aluminum Chassis

AMERIGON

ALUM VS STEEL VEHICLE PERFORMANCE COMPARISON

—

Prepared by: T. Cameron July 14,1997

This report will status and compare an aluminum frame AEV and a steel frame AEV. A comparison of weight, cost, and performance will be analyzed.

WEIGHT

The weight of the four complete aluminum chassis, as a running chassis only (less body attachments) is shown below.

AL-AEV1	101 lbs
AL-AEV2	100 lbs
AL-AEV3	99 lbs
AL-AEV4	100 lbs

It is estimated that body attachments would add 7 to lbs in aluminum.

The weight of four complete steel chassis, with all body attachments, is shown below.

AEV-1	152 lbs
AEV-2	151 lbs
AEV-3	152 lbs
AEV-4	151 lbs

The aluminum chassis is 42 lbs lighter, giving a saving of 28%.

MATERIAL COST

At the time this report was written the price of both aluminum and steel in the structural shapes required to fabricate the AEV chassis were investigated. Prices were compared both by the foot and by the pound. Several material suppliers in the Los Angeles area quoted the tubing in runs over 50,000 feet. The AEV chassis requires 125 feet of tubing.

These quotes were averaged to give the values shown below.

Aluminum	$1.50 per foot	$1.20 per lb	$128.00 per chassis
Steel	$ .50 per foot	$ .40 per lb	$61.00 per chassis

A secondary material cost to consider is the cost to put a protective coating, or paint on a chassis. The aluminum chassis would be self protected in its own oxidation, and would not require any coating or painting. It has been estimated that the cost to prepare and wet paint, a steel chassis is $200 in the prototype stage and $45.00 in production

The aluminum chassis material cost is $22 more, or 17% more than steel in production

FABRICATION COST

The AEV chassis has been designed to be MIG welded by hand. Fabricating the chassis with a simple clamping fixture required 40 hours by a union welder at the Alameda NAS. The aluminum chassis were Mig welded with aluminum wire using the same technique. Because of the extra preparation and cleanliness required for welding aluminum it took 48 hours per chassis.

Welding fabrication production cost for union welder approx. $20.00 per hour

Aluminum $20/hr x 48hrs = $ 960.00

Steel $20/hr x 40hrs = $ 800.00

With production fixtures, the estimated time requirement to weld the chassis is 8 hours for steel and 81/2 hours for aluminum, or a difference of 6%

Prototype Costs

ALUMINUM		STEEL	
Material	$128.00	Material *	$261.00
Fabrication	$960.00	Fabrication	$800.00
total	$1088.00	**total**	$1061.00

Production Costs

ALUMINUM		STEEL	
Material	$128.00	Material *	$106.00
Fabrication	$170.00	Fabrication	$160.00
total	$298.00	**total**	$266.00

*includes painting costs

PERFORMANCE

The structural performance was analyzed in the attached Finite Element Analyses Report, (report # CSG-2). This data was then checked in a laboratory test, see attached Test Report (pv-test7).

A summary of these results are shown in the table below.

	ALUMINUM	STEEL
FEA DATA	1190 ft-lbs / deg	1550 ft-lbs / deg

	ALUMINUM	STEEL
LAB DATA	1000 ft-lbs / deg	1200 ft-lbs / deg

Acceleration tests of the four aluminum running chassis, and three steel running chassis, from 0 to 30 kph are shown below

Acceleration 0 to 30 kph

AL-AEV1	2.7 sec		AEV1	2.9 sec
AL-AEV2	2.7sec		AEV2	2.9 sec
AL-AEV3	2.7sec		AEV3	2.8 sec
AL-AEV4	2.8 sec			

Range test data from a full SOC has been summarized in the following table.

Steady state range test at 40 kmph (without body)

AL-AEV1	105 km		AEV1	100 km
AL-AEV2	103 km		AEV2	103 km
AL-AEV3	102 km		AEV3	102 km
AL-AEV4	103 km			

SUMMARY

The aluminum chassis will provide a 28 percent weight savings, with a 11 percent cost penalty in production at the chassis level. A complete full bodied AEV has a curb weight of 1470 lbs. The 42 pound weight savings of an aluminum chassis would contribute a total of 2.8 percent of the total vehicle weight. This weight savings would enhance the acceleration and range performance by 1-3% percent.

AMERIGON

FINITE ELEMENT ANALYSIS REPORT
AEV CHASSIS ALUMINUM / STEEL

REPORT #: CSG-2

DATE: 5-21-97

STRUCTURE: AEV aluminum vs. steel

STRESS ANALYST: Todd Cameron

SUMMARY: The main roll of the space frame chassis is to provide the occupants with the maximum possible protection from impact from any direction. In addition to occupant protection a criteria of the space frame design is to provide structure to increase the bending and torsional rigidity of the vehicle. Increased structural rigidity improves vehicle handling by allowing the suspension components to control a larger percentage of the vehicles kinematics.

In order to achieve these design goals, finite element analysis was employed to help design the steel space frame chassis. This same FEA was used to convert the space frame from steel to aluminum. Several iterations of FEA models were analyzed until the performance of the aluminum chassis was comparable to the proven steel chassis. This analysis was used to help determine the cross sections and wall thickness of the aluminum chassis members.

Modeling started with a FEA model of the current steel chassis. This model consist of more than 10,000 elements see (Fig 1). Loads and restraints were modeled in to simulate the torsional rigidity testing, in the exact way that it would be tested in the laboratory. Once a consistent steel model was running, material properties, and readily available cross sections of aluminum were substituted in. The same load and restraint conditions were applied to both the steel and aluminum models. The results of the analysis were post processed for stress deflection and fatigue. Optimization was performed by repeated thinning of the wall thickness and decreasing the cross section of the least effective member.

RESULTS: The FEA model of the steel chassis gave a result of 1550 ft-lbs/deg in torsional rigidity see (Fig 2). The FEA of the aluminum gave a result of 1495 ft-lbs/deg see (Fig 3). These results were obtained with aluminum cross sections of 2" x 3" side rails, 2" x 2" crossmembers, and 2" diameter cantrails all with 1/8 inch wall thickness. A decision was made to decrease the cross sections to sizes similar to the steel chassis so that the components attached to the chassis would require a minimum amount of redesign and rework. Another model was created using 1.5" x 2.5" siderails, 1.5" x 1.5" crossmembers, and 1.25" diameter cantrails, all with 1/8 inch wall thickness. The torsional rigidity of this model was 1190 ft-lbs/deg.

CONCLUSION: Laboratory tests of torsional rigidity for both the aluminum and steel chassis were conducted see attached test report (pv-test7). A summary of the results is shown in the table below.

	ALUMINUM	**STEEL**
FEA DATA	1190 ft-lbs / deg	1550 ft-lbs / deg
LAB DATA	1000 ft-lbs / deg	1200 ft-lbs / deg

A possible explanation for the discrepancy between the FEA and lab data could be the ideal conditions modeled in the joints and end restraints of the FEA model. It would be best to re-process the FEA model allowing a small percentage of flex to be modeled in, until a closer match is made between the model and the lab data.

These figures may be adequate for a vehicle of this weight, as 1200 ft-lbs is probably the maximum static stress, and one degree of chassis distortion does not seem excessive.

AMERIGON

TEST REPORT

TITLE: Chassis Stiffness

REPORT#: pv-test7

DATE: May 25, 1997

CONDITIONS: n/a

TIRE PRESS: n/a

GVW: n/a

VEH #: AL-AEV1 / AEV4

TEST ENGR: P.Van Valkenburgh

INSTRUMENTATION: Mitutoyo Digital depth gauge

CALIBRATION: 3/96

TEST TRACK/COURSE: Labratory surface plate

TEST DESCRIPTION:
Torsional stiffness of the entire frame was measured by twisting the bare AEV frame on the bedplate. Extended beams were attached across the frame at the front and rear shock mount locations. Diagonally opposite corners were supported on jackstands. One remaining corner was tied down to the bedplate, and the diagonally opposite corner was loaded with 150 pounds at an 8-foot arm. Moment arm is the beam length from load to jackstand, and arm deflection divided by beam length is the sine of the deflection angle.

RESULTS:
Torsional rigidity:

Steel chassis with updated shock mounts	1200 ft-lbs/deg
Aluminum chassis with four bond joints	1000 ft-lbs/deg

CONCLUSION:
These figures may be adequate for a vehicle of this weight, as 1200 ft-lbs is probably the maximum static stress, and one degree of chassis distortion does not seem excessive.

COMMENTS:
Maximum windshield frame distortion under chassis torsional loading was measured to find whether a bonded flush windshield would be acceptable. Maximum static torsional load is assumed to be when the car is fully loaded and parked diagonally on an incline, with the most lightly loaded wheel off the ground. Reva 3 was stressed before the windshield was installed. A similar-size 1/4-inch ABS panel was installed, attached rigidly only at the bottom edge. The location of the top two corners was marked on the body before and after twisting the chassis. The maximum displacement of the frame with respect to the windshield was 0.140 inch laterally.

This indicates that a reasonably thick silicone bond strip would provide adequate displacement, without cracking the windshield, and might in fact add some torsional stiffness to the frame.

Appendix 2: Summary performance test report on BEV

AMERIGON

PERFORMANCE TEST REPORT

TITLE: AEV Verification Test

REPORT#: tc-test2

DATE: July 31, 1997

CONDITIONS: n/a

TIRE PRESS: 44 psi

GVW: see below

VEH #: AEV1 , AEV2, AEV3

TEST ENGR: P.Van Valkenburgh

INSTRUMENTATION: Fifth Wheel / microcomputer

TEST TRACK/COURSE: Arrow Hwy below dam

TEST DESCRIPTION:

Verification testing of the full bodied AEV vehicles was completed to document and confirm the performance of the vehicles. The testing included acceleration, top speed, gradeability, stopping distance, range and turning circle. The vehicles were also run through several kilometers of documented road testing in order to assure reliability.

RESULTS:

	GVW (LBS)	ACCEL (0-30 SEC)	TOP SPD (km/h)	GRADE (%)	STOP from 30mph	RANGE (km)	TURN (meters)
AEV1	1461	4.1	66.4	27	9.7 m	106.0	7.4
AEV2	1453	3.9	67.6	25	12.1 m	104.7	7.6
AEV3	1472	4.5	65.5	25	12.8 m	104.6	7.4

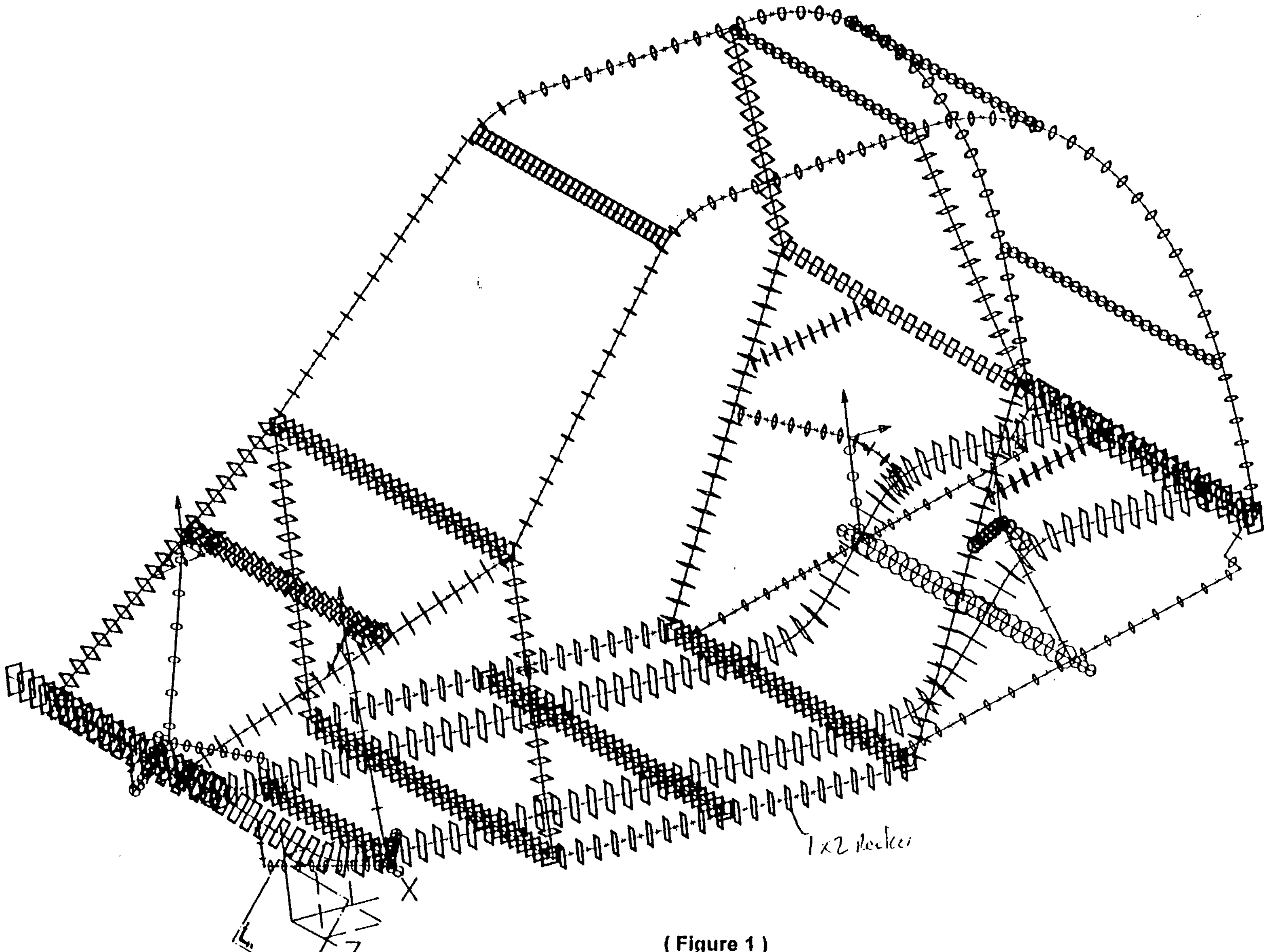
Final vehicle odometer readings (8-5-97)
AEV1 667 km
AEV2 461 km
AEV3 944 km

CONCLUSION:

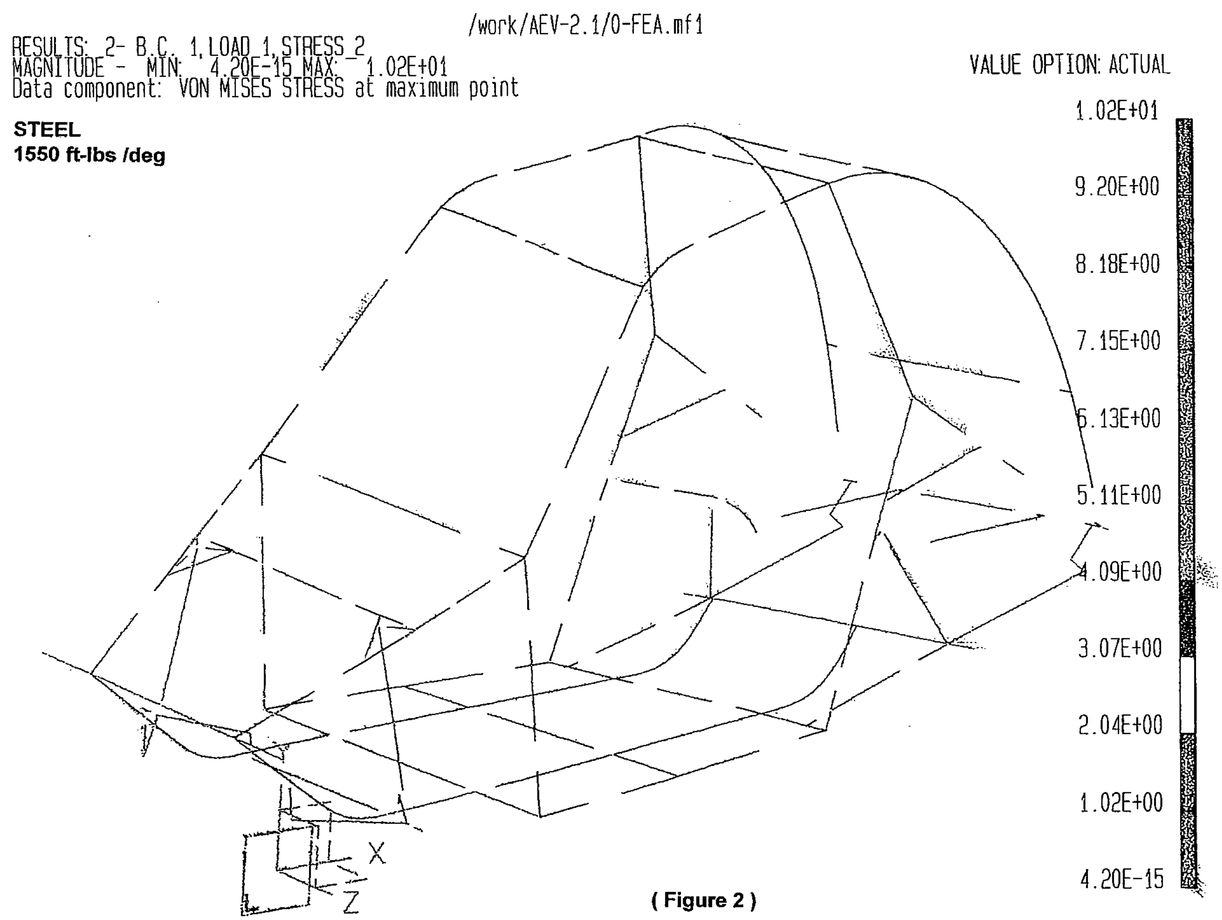
No major reliability problems occurred during testing. The performance was in check with the requirements. The speedometers have an error of 10 to 13 percent. The results presented are actual data (km). The range test was completed without data acquisition and was not to a complete discharge. Original data sheets are in the test file.

APPROVAL: [signature]

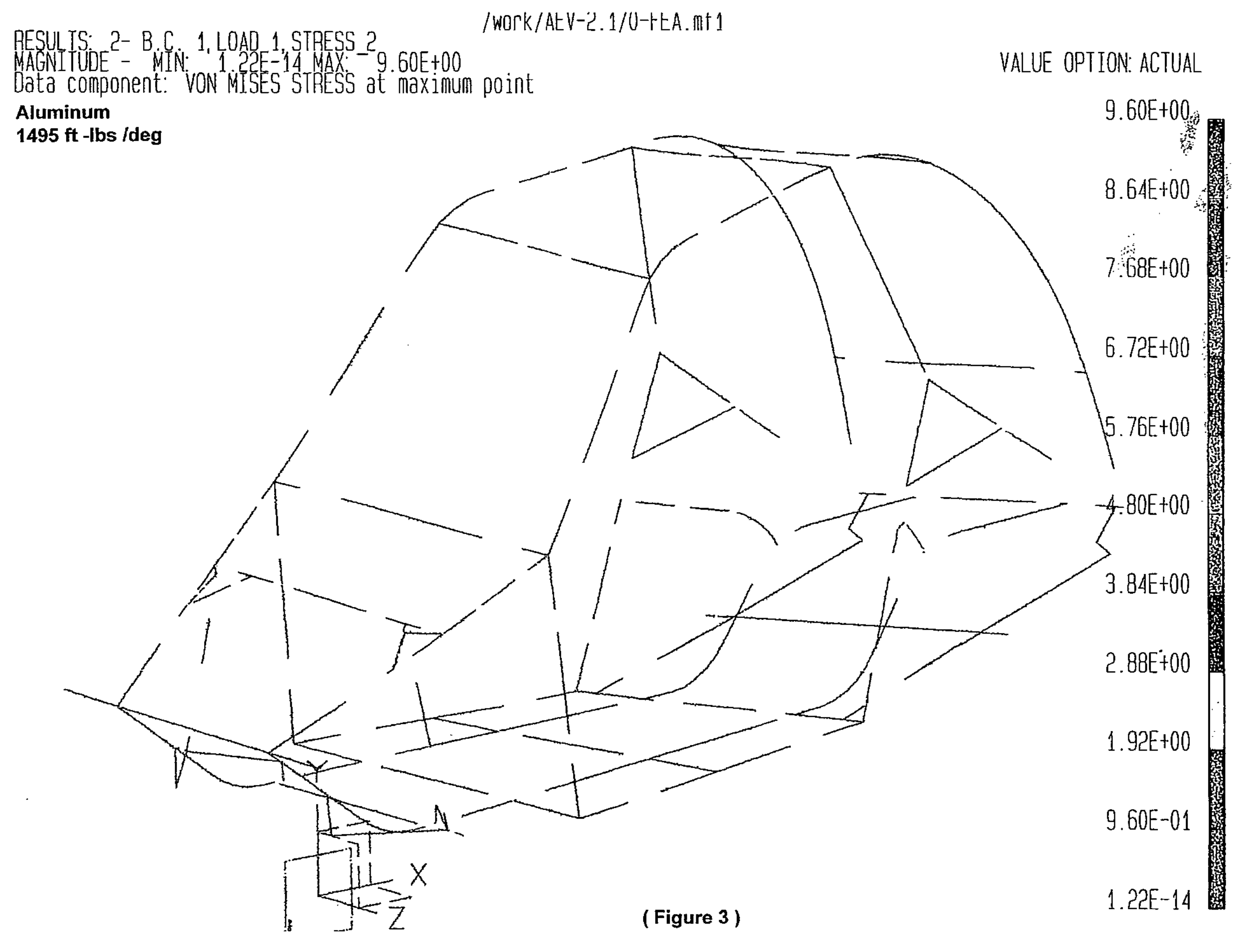
DATE: 7/31/97



(Figure 1)


/work/AEV-2.1/0-FEA.mf1
RESULTS: 2- B.C. 1,LOAD 1,STRESS_2
MAGNITUDE - MIN: 4.20E-15 MAX: 1.02E+01
Data component: VON MISES STRESS at maximum point
STEEL
1550 ft-lbs /deg
VALUE OPTION: ACTUAL
1.02E+01
9.20E+00
8.18E+00
7.15E+00
6.13E+00
5.11E+00
4.09E+00
3.07E+00
2.04E+00
1.02E+00
4.20E-15
X
Z

(Figure 2)


/work/AEV-2.1/U-FEA.mf1
RESULTS: 2- B.C. 1,LOAD 1,STRESS 2
MAGNITUDE - MIN: 1.22E-14 MAX: 9.60E+00
Data component: VON MISES STRESS at maximum point
Aluminum
1495 ft -lbs /deg
VALUE OPTION: ACTUAL
9.60E+00
8.64E+00
7.68E+00
6.72E+00
5.76E+00
4.80E+00
3.84E+00
2.88E+00
1.92E+00
9.60E-01
1.22E-14
X
Z

(Figure 3)

Appendix 6: BEV and EV4 Specifications

REVA Technical Specifications

Type	2-door, hatchback, right-hand-drive
Payload (2 adults, 2 children & cargo)	225 kg (496 lb)
Range (with full payload)	135 km (84 mi) @ 40 kph (25 mph) constant speed to 80% Dod 71 km (44 mi) on Indian Standard Driving Cycle to 80% Dod
Top speed	65 kph (40.6 mph)
Curb Weight	650 kg (1,430 lb)
F/R Weight Ratio	40% / 60%
Wheel Base	1650 mm (65.0 in)
Track	1181 mm (46.5 in)
Length	2638 mm (103.9 in)
Width	1324 mm (52.1 in)
Height	1510 mm (59.4 in)
Ground Clearance (min.)	150 mm (5.9 in)
Turning Radius (max.)	3505 mm (138 in)
Maximum Gradeability:	20% with full payload
Battery Weight	240 kg (528 lb)
Battery Capacity (C-20)	235 AH
Battery Energy Density (C-20)	45 WH/kg
Battery Pack Voltage	48V nominal
Battery Pack Current	450A maximum
Controller / Charger / EMS (Integrated Power System)	Controller Seperately excited with regenerative braking Charger: 220 V, 12 A, 2kW Standard Indian 15A wall plug EMS: Intelligent fuel gauge & battery mgmt. System DC-DC converter: 300 W max.
Charge Time	80% in 3 hrs, 100% in 8 hrs
Body Material	High impact ABS vacuum formed panels. (Bumpers: rotomolded HDPE)
Frame Type	Welded tubular space frame
Suspension	MacPherson strut (front) Solid axle (rear)
Tires	145/60R14
Wheels	3.5" x 14" Aluminum Alloy
Brakes	Four wheel dual circuit hydraulic drum brakes Integrated regenerative braking
Motor	DC Seperately excited, 6 hp continuous (17 hp peak)
Transmission	7:1 single gear reduction directly coupled to motor driving rear wheels

C.Maini
08/19/97

AMERIGON EV4 SPECIFICATIONS

1.0 Vehicle Type

Passenger:	4
Type:	2 Door Hatch Back
Drive:	Front Wheel (Motor Direct Drive)

2.0 Physical Dimensions

Overall Length:	4,055 mm
Width:	1,675 mm
Height:	1,490 mm
Wheelbase:	2,485 mm
Track Front:	1,440 mm
Rear:	1,425 mm
Curb Weight:	1,400 kg (target) 3080 lb.
Weight Distribution:	50/50 With One Occupant

3.0 Clearances

Nominal Ground Clearance:	165 mm
Depth of pothole that can be cleared:	N.A.
Angle of ramp that can be cleared:	15° (Min.)
Approach Angle:	17° (Min.)
Departure Angle:	17° (Min.)
Height of curb that can be cleared:	N.A.
Front wheel to fender:	Amerigon recommends 30-40 mm (Samsung to verify)
Rear wheel to fender:	Amerigon recommends 30-40 mm (Samsung to verify)

4.0 Acceleration and Power

Acceleration:	0 to 400 m : 21.0 sec.
	0 to 100 kph : 16 sec.
Max. Speed:	More than 120 km/h
Hill Climbing Ability:	20% Min. at 15 kph for up to 5 Min.

Vehicle Specification Cont.

5.0 Range (Maintenance Free Lead Acid Battery)

Constant Speed (40 kph): More than 150 km
City Drive (Seoul): More than 60 km

6.0 Brake

Performance

- 60 to 0 kph: 43 m (max.)
- 30 to 0 kph: 18 m (max.)
- Max. Speed to 0 kph: 75 m
- Max. deceleration by brakes: 1g (max.)
- Wet Pavement 60 to 0 kph: 52 m (max.)

Uniformity of braking deceleration

Spec to be developed by Samsung

Regeneration before brake application

Up to 0.3 g (Adjustable by controller) when acceleration pedal is fully lifted. Maximum regen must be adjustable by Samsung

Regenerative during brake application

Up to 0.6 g (Adjustable by controller) when accelerator is fully lifted. Maximum regen must be adjustable by Samsung

Response Time

- Response Time from pedal application: 100 msec (max.)
- Response Time from pedal release: 100 msec (max.)

Vehicle stability during braking

Must be able to maintain control under heavy braking. Maximum 0.25 degree yaw.

Brake noise: Less than 50 db
Parking Brake: Meets FMVSS standards

7.0 Suspension

According to Basic Vehicle (Carry Over)

8.0 Tire and Wheel

Tire Size: 175/70/R13 - use Goodyear Invicta GLR
Temp.: T105/70/D14
Wheel Size: 5.5 J x 13

Vehicle Specification Cont.

9.0 Handling

Lateral Acceleration:	0.75 g (min.)
Degree of body roll:	3.5 degree max. at 0.5 g 5.0 degree max. at max. accel.

10.0 Drive Train

Motor & Controller Type:	AC Induction
Power:	Satisfy Vehicle Performance
Energy Used:	Satisfy Driving Range
Transmission Type:	Single Speed
Final Drive:	Differential

11.0 Occupant Interaction

Display Supported:

Speedometer, Odometer, Turn Signal, Drive Engaged, Battery Level, Motor Temp., Lights for Brake, High Beam Low Energy Remaining, Seat Belt, Door Opening, Hood Opening, Refer to Ordering Spec.

12.0 Occupant Protection and Safety

Crash Worthiness:	Per Amerigon's Specification (Do not do vehicle tests, Simulation only)
Seat Belts:	Frame will be hard points for 3 points belts
High Voltage Isolation	Incorporated in controller

High Voltage Crash Disconnect

Battery Containment Requirements

Fail-safe models for loss of power brakes and steering revert to manual

Field of Vision:	According to Samsung SEV - III
Do not start*:	At Charging To prevent quick start, driver has to foot brake pedal when start

13.0 Durability

Warranty: 1 year 24,000 km (min.)

Target Life

Batteries:	1,000 Recharge cycle
Brakes:	120,000 km
Shock Absorbers:	150,000 km
Tire:	50,000 km

Battery pack replacement in field service possible

Vehicle Specification Cont.

14.0 Maintenance

Periodic maintenance: Check transmission oil
Check coolant

15.0 Environment

Temp. Range:	-20°C to 40°C Operating
	-40°C to 85°C Storage
Humidity Range:	0 to 100% Non-condensing
Rain on Chassis:	Must not damage or impair function
	Must not allow any current leakage from/into electrical system

16.0 Interfaces

Electrical Supply to Charger:	220 V 15 Amps. 60 Cycles
Test Equipment Interface:	RS 232 C
Tow hooks and towing provisions 2 in front, 1 in rear	
Vehicle ID Number:	Assigned by Samsung
Require warning level:	SAE standard on high voltage systems

Appendix 7: EV4 Test Report

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
1.0	***Vehicle Type***									
1.1	Passenger Capacity	Full vehicle standing inspection	4 passengers	Number of seats	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
1.2	Body Type / Style	Full vehicle standing inspection	2 door hatchback	Compare against standard body types	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
1.3	Drive Type:	Full vehicle standing inspection	front wheel drive, motor direct drive	Compare against standard drive types	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
2.0	***Physical Dimentions***									
2.1	Overall Length	Full vehicle standing measurement	4055mm	Front bumper to rear bumper	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
2.2	Width	Full vehicle standing measurement	1675mm	Left side view mirror to right body apex	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
2.3	Height	Full vehicle standing measurement	1490mm	Ground to roof apex	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
2.4	Wheelbase	Full vehicle standing measurement	2485mm	Front wheel center to rear wheel center	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
2.5	Track, Front	Full vehicle standing measurement	1440mm	Tread center of front left tire to tread center of front right tire	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
2.6	Track, Rear	Full vehicle standing measurement	1425mm	Tread center of rear left tire to tread center of rear right tire	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
2.7	Curb Weight	Full vehicle standing measurement	1400kg (3080 lb.)	Measure vehicle with weight scales placed under each wheel	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
2.8	Weight Distribution	Full vehicle standing measurement	50/50 , 1 occupant	Measure vehicle with weight scales placed under each wheel	Meet customer specifications.	Amerigon	0	Don C.	Dave B.	
3.0	***Clearances***									
3.1	Nominal Ground Clearance	Full vehicle standing measurement	165mm	Distance between ground and lowest point on vehicle, except for wheels, tires, and brakes	Meet customer specifications.	Amerigon.	0.05	Don C.	Dave B.	
3.2	Angle of Ramp that can be cleared	Full vehicle standing test	15°	Place 1 meter ramp between front tire ground contact point and upper most contact point of lower vehicle body	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
3.3	Approach angle	Full vehicle standing test	17°	see above	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
3.4	Departure Angle	Full vehicle standing test	17°	similar to above description, but rear tire ground contact point is used	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
3.5	Front wheel to fender clearance	Full vehicle standing measurement	no less than 30mm, no more than 40mm	Distance between upper tire tread and fender lip	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
3.6	Rear wheel to fender clearance	Full vehicle standing measurement	no less than 30mm, no more than 40mm	Distance between upper tire tread and fender lip	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
4.0	***Acceleration and Power***									
4.1	Acceleration	Full vehicle driving test	21 seconds	Time from start (0 kph) to 400m length marked by cones (with DAQ)	Meet customer specifications.	Pomona	3	Don C.	Dave B.	
4.2	Acceleration	Full vehicle driving test	16 seconds	Time from start (0 kph) to 100 kph as indicated by DAQ	Meet customer specifications.	Pomona	3	Don C.	Dave B.	
4.3	Maximum Speed	Full vehicle driving test	More than 120 km/hr (75 mph)	Observe speedometer and speed indicated on DAQ	Meet customer specifications.	Pomona	0.2	Don C.	Dave B.	
4.4	Hill Climbing Ability	Full vehicle driving test	20 % grade for 0.2, @ 15 km/hr	Perform test run and verify that no damage occurs to vehicle. Measure motor temperatures.	Meet customer specifications.	Street Drive Sierra Madre	0.5	Don C.	Dave B.	
5.0	***Range***									
5.1	Constant Speed (40 kph)	Full vehicle driving test	More than 150km	Drive at 40 kph until SOC = 20%. Measure total range covered.	Meet customer specifications.	Pomona	3	Don C.	Dave B.	
5.2	City Drive (Seoul)	Full vehicle driving test	More than 60 km	Drive city route until SOC = 20%. Measure total range covered.	Meet customer specifications.	Irwindale Swap Meet Grounds	3	Don C.	Dave B.	
6.0	***Braking***									
6.1	Performance, 60- to 0 kph	Full vehicle driving test	43m	Measure braking distance from brake pedal actuation to vehicle stop from 60 kph	Meet customer specifications.	Irwindale Swap Meet Grounds	0.5	Don C.	Dave B.	
6.2	Performance, 30- to 0 kph	Full vehicle driving test	18m	Measure braking distance from brake pedal actuation to vehicle stop from 30 kph.	Meet customer specifications.	Irwindale Swap Meet Grounds	0.5	Don C.	Dave B.	
6.3	Max speed to 0 kph	Full vehicle driving test	75m	Measure braking distance from brake pedal actuation to vehicle stop from full speed.	Meet customer specifications.	Pomona	0.5	Don C.	Dave B.	
6.4	Max. deceleration by Brakes	Use data from #6.1 to 6.3	1g (max)	Calculate deceleration with speed and distance data	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
6.5	Wet Pavement, 60 to 0 kph	Full vehicle driving test	52m	Measure braking distance from brake pedal actuation to vehicle stop from 60 kph on wet ground.	Meet customer specifications.	Irwindale Swap Meet Grounds	0.5	Don C.	Dave B.	
6.6	Deceleration by regen braking	Full vehicle driving test	0.3g	Measure max deceleration due to regen brakes used alone.	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
6.7	Deceleration by regen and hydraulic brakes	Full vehicle driving test	0.6g	Measure max deceleration due to regen plus hydraulic brakes	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
6.8	Braking Response time	Full vehicle driving test	100 msec (max)	Obtain differential time data from brake pedal switch to pressure transducer in brake lines/ accelerometer on DAQ	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
6.9	Braking Yaw Stability	Full vehicle driving test	0.25° yaw (max)	Observe brake dive with level indicator mounted in vehicle	Meet customer specifications.	Irwindale Swap Meet Grounds	0.5	Don C.	Dave B.	
6.10	Brake Noise	Full vehicle driving test	Less than 50 dB	Measure dB with dB meter placed near brake rotor	Meet customer specifications.	Irwindale Swap Meet Grounds	0.5	Don C.	Dave B.	
6.11	Parking Brake, meets FMVSS 571.105, S5.2	Full vehicle standing inspection	Parking Brake using friction brakes, actuated by solely mechanical means, in any functional vehicle condition	Inspection	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
6.12	Parking Brake FMVSS 571.105, S5.2a	Full vehicle standing inspection	Hand operated lever actuating force should not exceed 90 pounds	Measure force	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
6.13	Parking Brake FMVSS 571.105, S5.2.1	Full vehicle driving test	Parking brake under full engagement should hold vehicle on a 30% grade for 0.2, for both forward and reverse directions	Observe any wheel travel in 0.2	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
6.14	Parking Brake FMVSS 571.105, S5.3.1d	Full vehicle standing inspection	Indicator lamp should be on under parking brake engagement	Observe dash panel brake lamp, verify function	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	

7.0 Suspension

8.0 Tire and Wheel

8.1	Tire Size	Component inspection	175/70/R13, use Good year Invicta GLR	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
8.2	Temporary Spare Tire	Component inspection	T105/70/D14	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
8.3	Wheel Size	Component inspection	5.5 J x 13	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	

9.0 Handling

9.1	Lateral Acceleration	Full vehicle driving test	0.75 g (min)	Drive vehicle in 100' radius, observe maximum safe speed	Meet customer specifications.	Irwindale Swap Meet Grounds	0.2	Don C.	Dave B.	
9.2	Degree of Body Roll	Data from 9.1	3.5° max at 0.5g	Use level indictor and accelerometer on DAQ	Meet customer specifications.	Irwindale Swap Meet Grounds	0.2	Don C.	Dave B.	

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
9.3	Degree of Body Roll during acceleration	Data from 4.1	5.0° max at max. acceleration	Use level indictor and accelerometer on DAQ	Meet customer specifications.	Pomona	0.2	Don C.	Dave B.	
##	*Drive Train*									
10.1	Motor Controller Type:	Component inspection	AC Induction	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
10.2	Power:	Perform tests #4.1 and 4.2, 4.3 & 4.4	Satisfy Acceleration and Top Speed performance	Power is adequate if tests #4.1, 4.2, 4.3 & 4.4 are met	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
10.3	Energy Used:	Perform tests #5.1 & 5.2	Satisfy Driving Range	Energy in battery stack is adequate if tests #5.1 & 5.2 are met	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
10.4	Transmission Type:	Component inspection	Single Speed	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
10.5	Final Drive	Component inspection	Differential	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
##	*Occupant Interaction*									
11.1	Speedometer	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.2	Odometer	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.3	Turn Signal	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.4	Drive Engaged Lamp (Ready)	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.5	Battery Level	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.6	Motor Temp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.7	Lights for Brake	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.8	High Beam Control	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.9	Low Energy Remaining Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.10	Seat Belt	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.11	Door Opening	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.12	Hood Opening	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.13	Digital Clock	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.14	Current Meter	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
11.15	Warning Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.16	Turn Signal Lamps	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.17	EV Failure Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.18	Door Ajar Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.19	High Beam Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.20	Fog Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.21	Seat Belt Lamp	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
11.22	Rear Glass heater / defogger	Component inspection	Must be present		Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
##	Occupant Protection and Safety									
12.1	Crash Worthiness	Analysis	Amerigon Inc. Specification	Computer simulation is determined successful	Meet customer specifications.	Amerigon		Don C.	Dave B.	
12.2	Seat Belts	Component inspection	Three points secured to frame hard points	Inspection of hard points, number and location	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
12.3	High Voltage Isolation	Component inspection	Chassis frame and no HV components not energized from HV battery	test for voltage	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
12.4	High Voltage Crash Disconnect	Component inspection and analysis	High voltage disconnect switch function (open switch)	determine if switch is open or closed	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
12.5	Battery Containment	Component inspection	no spec.	subjective opinion of battery containment	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
12.6	Fail Safe Condition during loss of power brakes and steering	Component inspection and analysis	Revert to manual operation	steering and braking must be functional	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
12.7	Field of Vision	Full vehicle standing measurement	N/A, need to obtain from Samsung	TBD	Meet customer specifications.	Amerigon	0.5	Don C.	Dave B.	
12.8	Do not Start Condition	Component test	Vehicle should not turn on or move via motor use	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
##	Durability									
13.1	Warranty	Analysis	1 year		Meet customer specifications.			Don C.	Dave B.	
13.2	Target Life: Batteries	Analysis	1000 cycles		Meet customer specifications.			Don C.	Dave B.	
13.5	Target Life: Batteries	Analysis			Meet customer specifications.			Don C.	Dave B.	

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
13.6	Battery Pack Replacement in field possible	Analysis			Meet customer specifications.			Don C.	Dave B.	
##	**Maintenance**									
14.1	Check transmission oil	Full vehicle inspection	Check device, measure present	Inspection, Can checking be done?	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
14.2	Check coolant	Full vehicle inspection	Check device, measure present	Inspection, Can checking be done?	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
##	**Environment**									
15.1	Temperature Range	Component measurement and analysis	-20°C to 40°C Operating	Analysis, verify component temperature ranges comply with spec.	Meet customer specifications.	Amerigon	5	Don C.	Dave B.	
15.2	Temperature Range	Component measurement and analysis	-40°C to 85°C Storage	Analysis, verify component temperature ranges comply with spec.	Meet customer specifications.	Amerigon	5	Don C.	Dave B.	
15.3	Humidity Range	Component analysis	0 to 100% non-condensing	Analysis, verify component temperature ranges comply with spec.	Meet customer specifications.	Amerigon	5	Don C.	Dave B.	
15.4	Rain on Chassis	Full vehicle driving test	Must not damage, must not impair function, must not allow any current leakage from/into electrical system	Observe window and body sealing for water leaks. Inspection for water leaking. Use DVM to check for ground faults	Meet customer specifications.	Amerigon	1	Don C.	Dave B.	
##	**Interfaces**									
16.1	Electrical Supply to Charger	Component test	220V 15 Amp, 60 Hz	Locate charge port, Inspection of charger function (use DAQ for feedback)	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
16.2	Test equipment Interface:	Component test	RS 232 C	Inspection and test function w/ Personal Computer with 9 pin RS 232 C port	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
16.3	Tow Hooks and towing provisions	Component inspection	2 in front, 1 in rear	Inspection	Meet customer specifications.	Amerigon	0.2	Don C.	Dave B.	
16.4	Vehicle ID Number	Component inspection	Assigned by Samsung	Inspection	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
16.5	Require Warning Label	Component inspection	SAE standard on High Voltage systems	Inspection of label presence, printed in English (and Korean ?)	Meet customer specifications.	Amerigon	0.05	Don C.	Dave B.	
A	**Other Amerigon Tests**									
A1.0	Durability testing	Chassis and full vehicle driving test	None	Note any mechanical failures or changes in component structure and/or performance.	Improve durability of vehicle design.	Any		Don C.	Dave B.	

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
A2.0	Structural integrity	Chassis and full vehicle driving test	None	Watch for mechanical problems and listen for unusual noises	Empirically verify structural integrity of chassis and suspension components	Any		Don C.	Dave B.	
A3.0	Charging	Component test	None	AC current vs time, Buss current vs time, Buss voltage vs time, Battery SOC vs time, PCU temp, fan ON/OFF	Verify charging profile, determine charging efficiency, verify battery pack capacity	Amerigon		Don C.	Dave B.	
A4.0	Drive system cooling	Chassis driving test	None	Measure radiator inlet coolant temp, radiator exit coolant temp, ambient temp, Motor coolant exit temp, and air flow. Measure coolant pump volts and current.	Determine if radiator, hose routing, and fans are adequate for standard operation. Also determine if coolant pump flow can be increased.	Amerigon	2	Don C.	Dave B.	
A5.0	Power Steering	Chassis driving test	None	Power strg motor current and voltage	Determine appropriate fuse size and current limiting to keep pump operating under extreme condition. Adjust, place stops.	Amerigon	2	Don C.	Dave B.	
A6.0	Brake Vacuum Pump	Chassis driving test	None	Pump motor current and voltage	Determine power consumption	Amerigon	2	Don C.	Dave B.	
A7.0	Gear Box	Chassis driving test	None	Observe gear box NVH	Verify gear box NVH levels are acceptable	Amerigon	3	Don C.	Dave B.	
A8.0	EMS	Component test	None	Driver observation of dash fuel gauge	Verify function	Any		Don C.	Dave B.	
A9.0	Low Speed Coast Down	Full vehicle driving test	None	Rolling drag	Determine correctable sources of rolling drag	Street Drive Arrow Hwy Irwindale	3	Don C.	Dave B.	
A10.0	High Speed Coast Down	Full vehicle driving test	None	Aero Drag	Determine correctable sources of aero drag	Street Drive Arrow Hwy Irwindale	3	Don C.	Dave B.	
A11.0	High voltage harness durability	Component test	None	Test resistance of special connectors before and after use in the vehicle.	Anticipate warrantee problems with special connectors	Amerigon	3	Don C.	Dave B.	

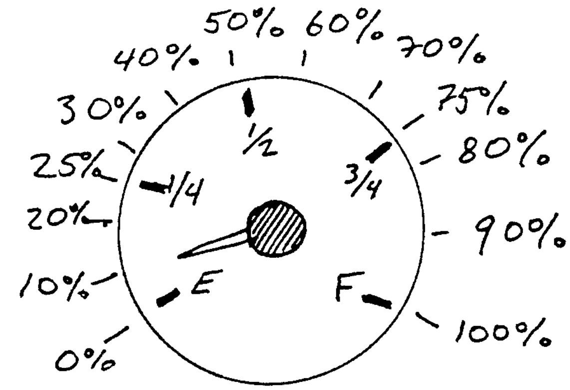
Don Campbell
David Bell

6/27/96

Introductory Test Plan for EV4

	Test Name	Test type	Parameter Spec.	Parameter Measurement	Purpose	Location	Hours	Test Engineer	Test Supervisor	Special Equipment
A12.1	Powertrain noise	Chassis standing test	10: 73 dB; 20: 84 dB; 30: 89 dB; 40: 93 dB; 50: 98 dB; 70: 100 dB	Measure dB A noise levels three feet in front of transmission with the front wheels jacked up, at 10, 20, 30, 40, 50 and 70 mph.	Help satisify A12.2. Improve customer satisfaction	Amerigon	3	Don C., Andy Swiecki	Andy Swiecki	
A12.2	Vehicle noise	Full vehicle driving test	None	Test dB A noise level 10 meters from vehicle travelling at 60 kph.	Korean Government Requirement. Improve customer satisfaction	Irwindale Swap Meet Grounds	3	Don C.	Dave B.	
	High Speed Coast Down	Full vehicle driving test	None	Aero Drag	Determine correctable sources of aero drag	Street Drive Arrow Hwy Irwindale	3	Don C.	Dave B.	
	Constant speed power	Full vehicle driving test	None	Vehicle speed, Buss current and voltage vs speed	Determine power draw versus speed curve.	Street Drive Arrow Hwy Irwindale	3	Don C.	Dave B.	

EV4 TEST FORM



Driver: ____________________

Date ____________________

Vehicle B C D

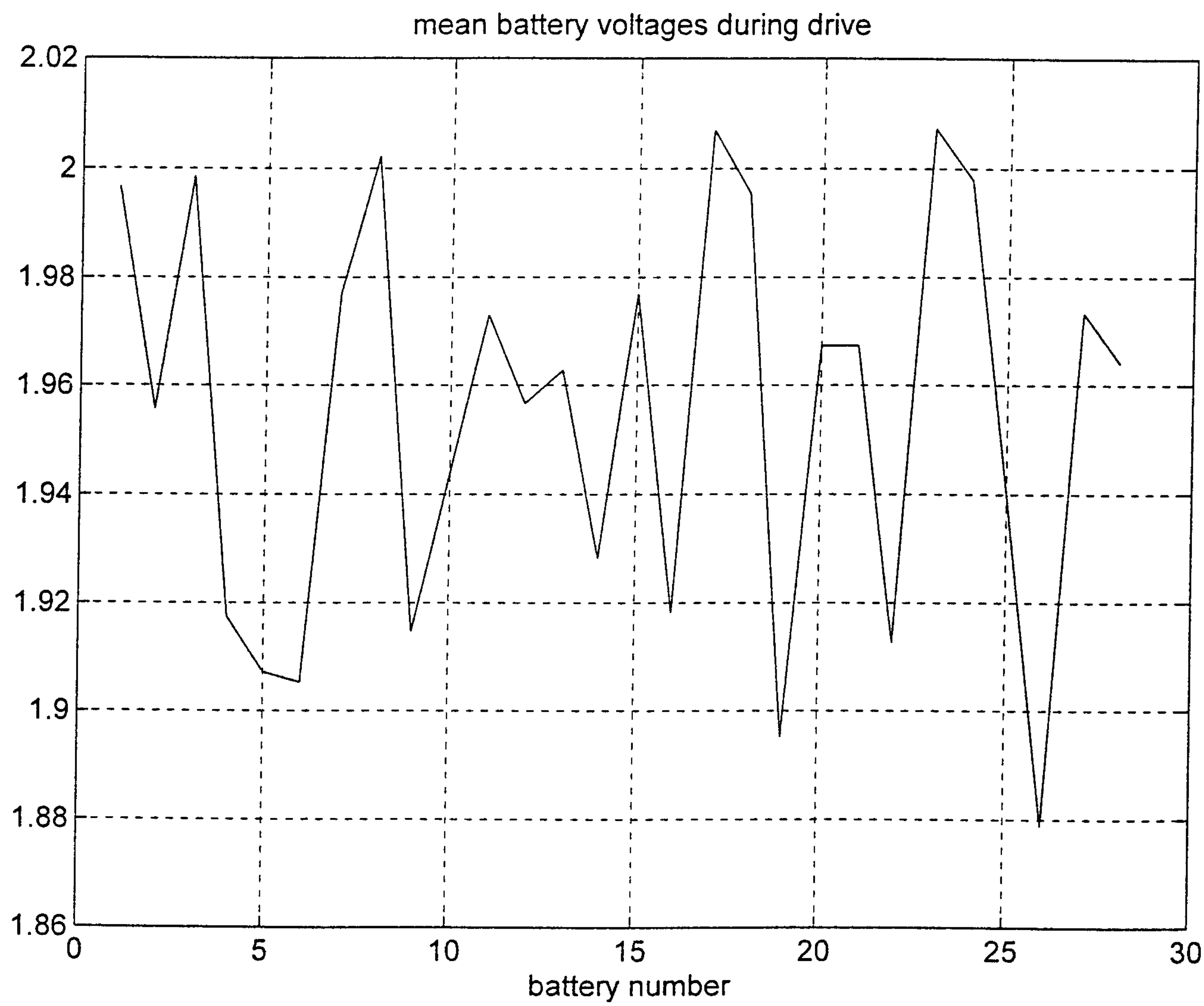
Drive Type: 1 2 3 4 5 (1 is casual, 5 is harsh)

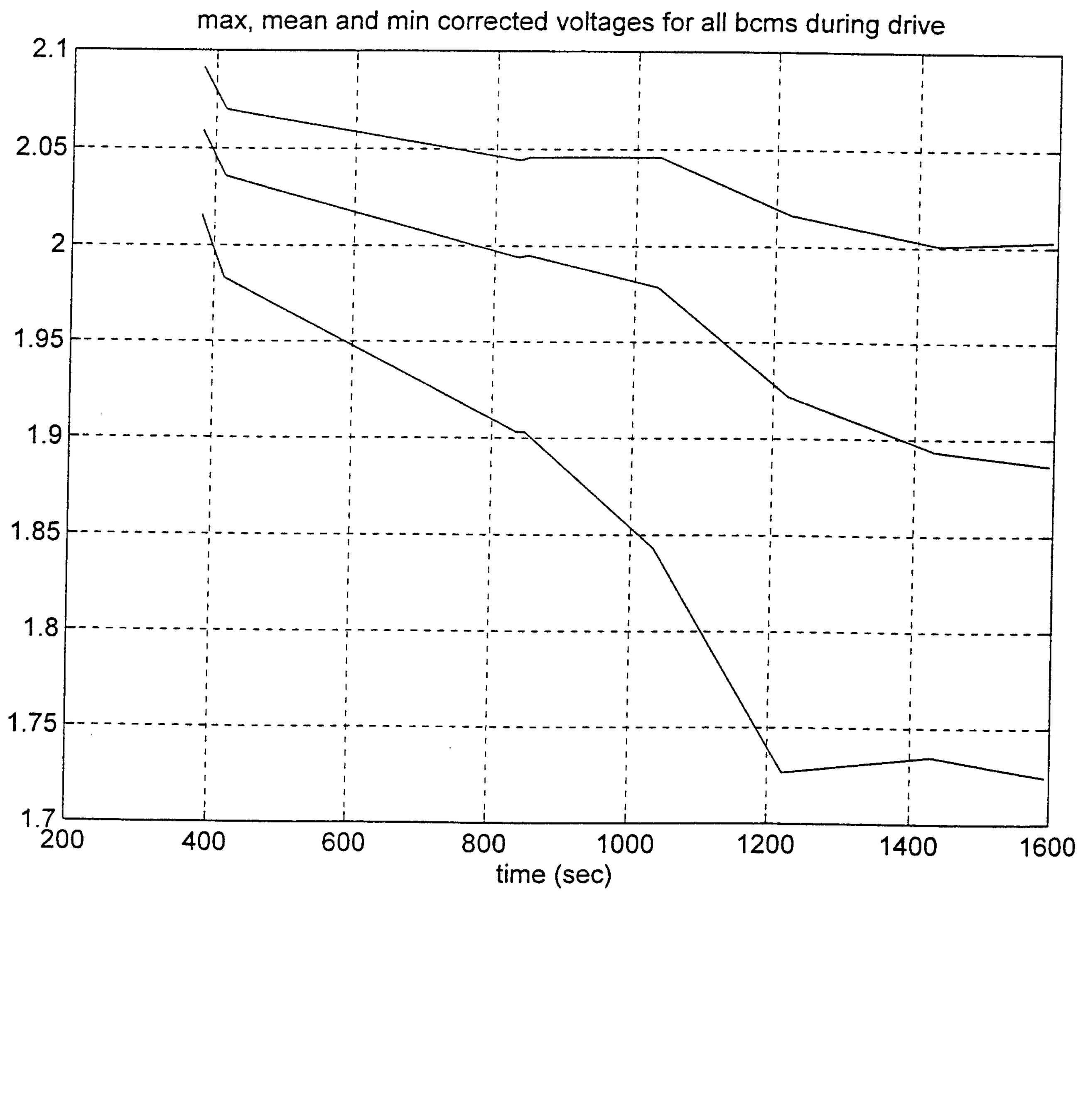
FUEL GAUGE DATA

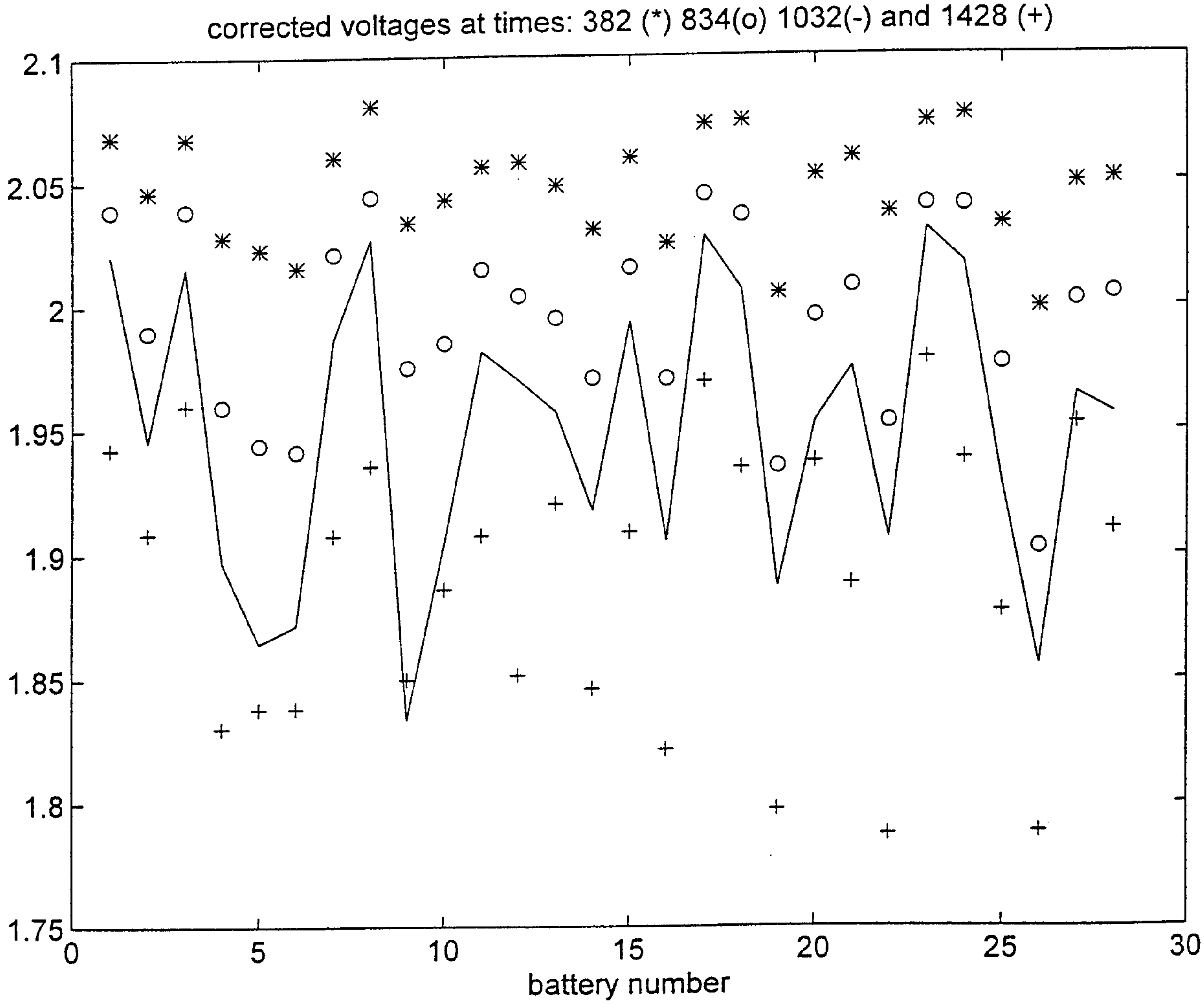
	Amp-hr	Gauge	Time	Notes
Start				
Solid light				
Flashing light				
Finish				

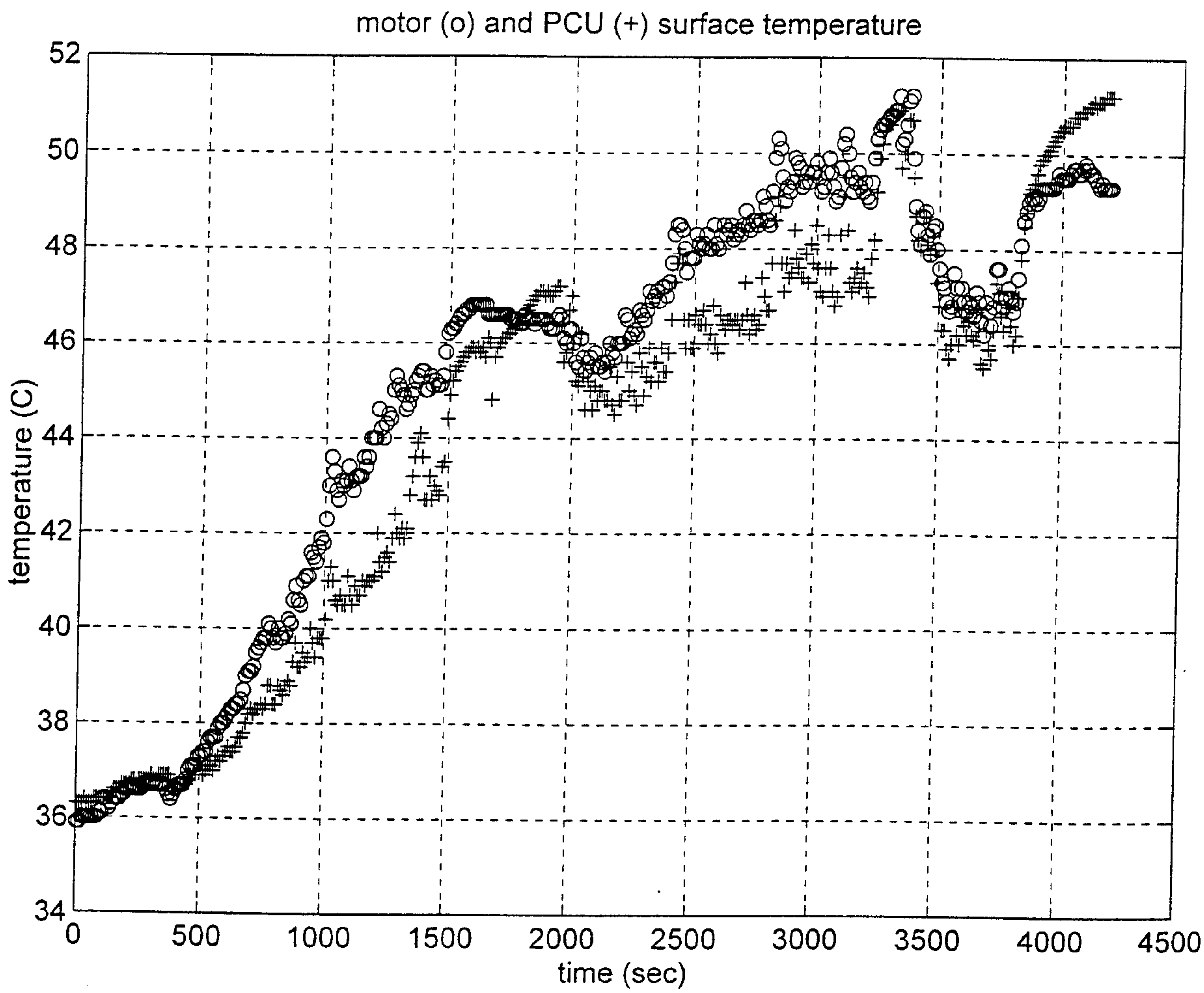
DRIVE DATA

Time	Odometer	Amp-hr	Gauge	Notes

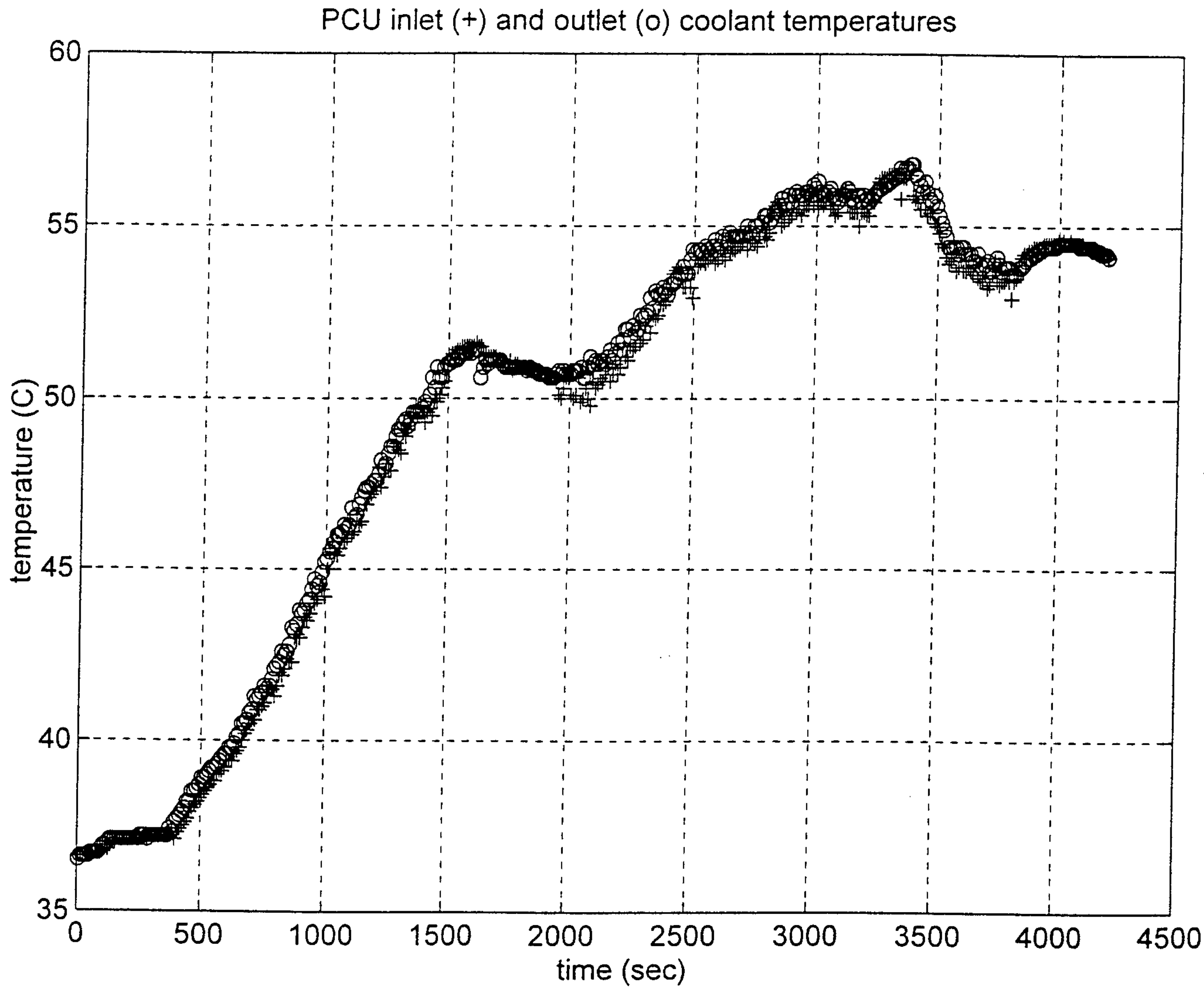

mean battery voltages during drive
2.02
2
1.98
1.96
1.94
1.92
1.9
1.88
1.86
0
5
10
15
20
25
30
battery number


max, mean and min corrected voltages for all bcms during drive
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
200
400
600
800
1000
1200
1400
1600
time (sec)

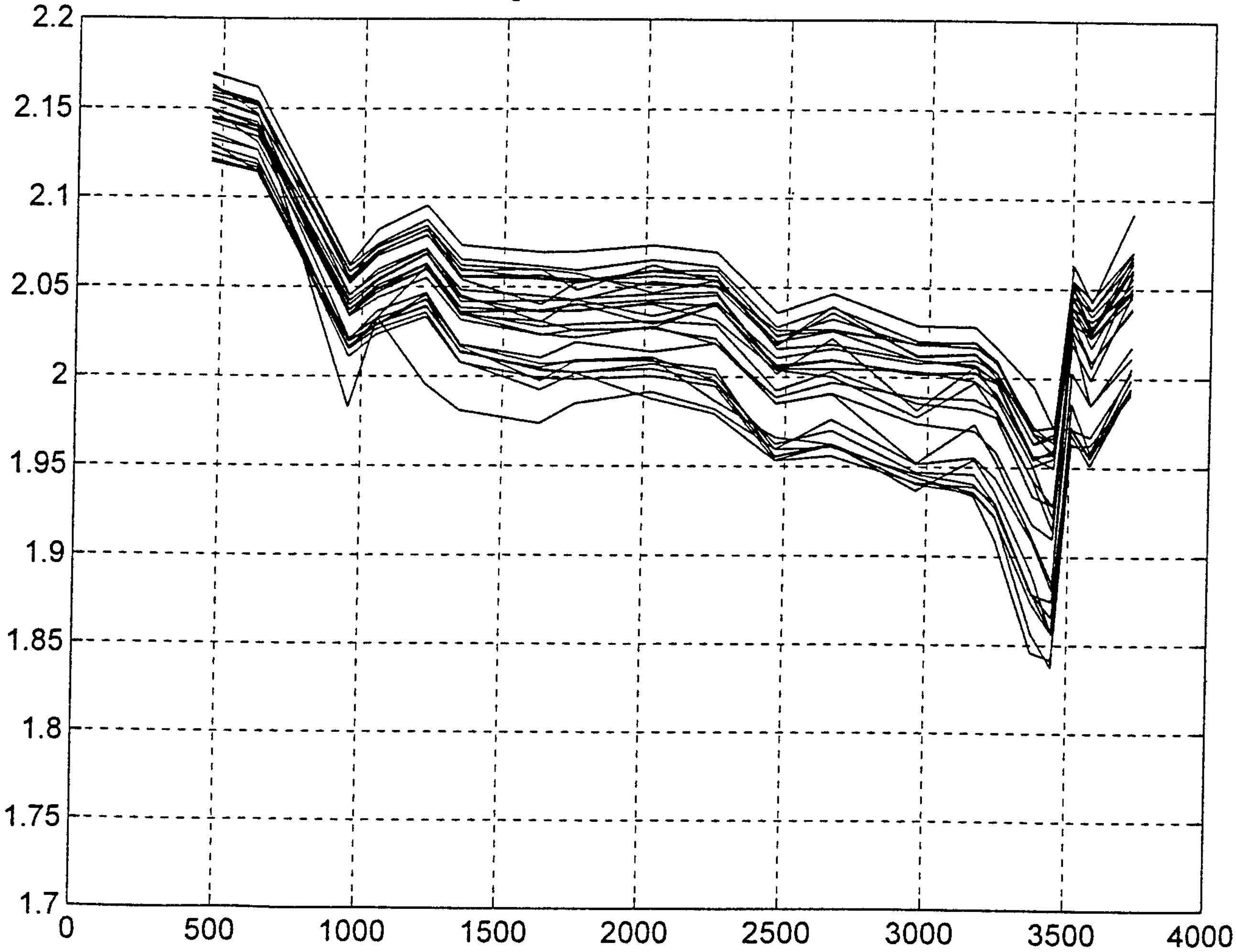

corrected voltages at times: 382 (*) 834(o) 1032(-) and 1428 (+)
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
0
5
10
15
20
25
30
battery number



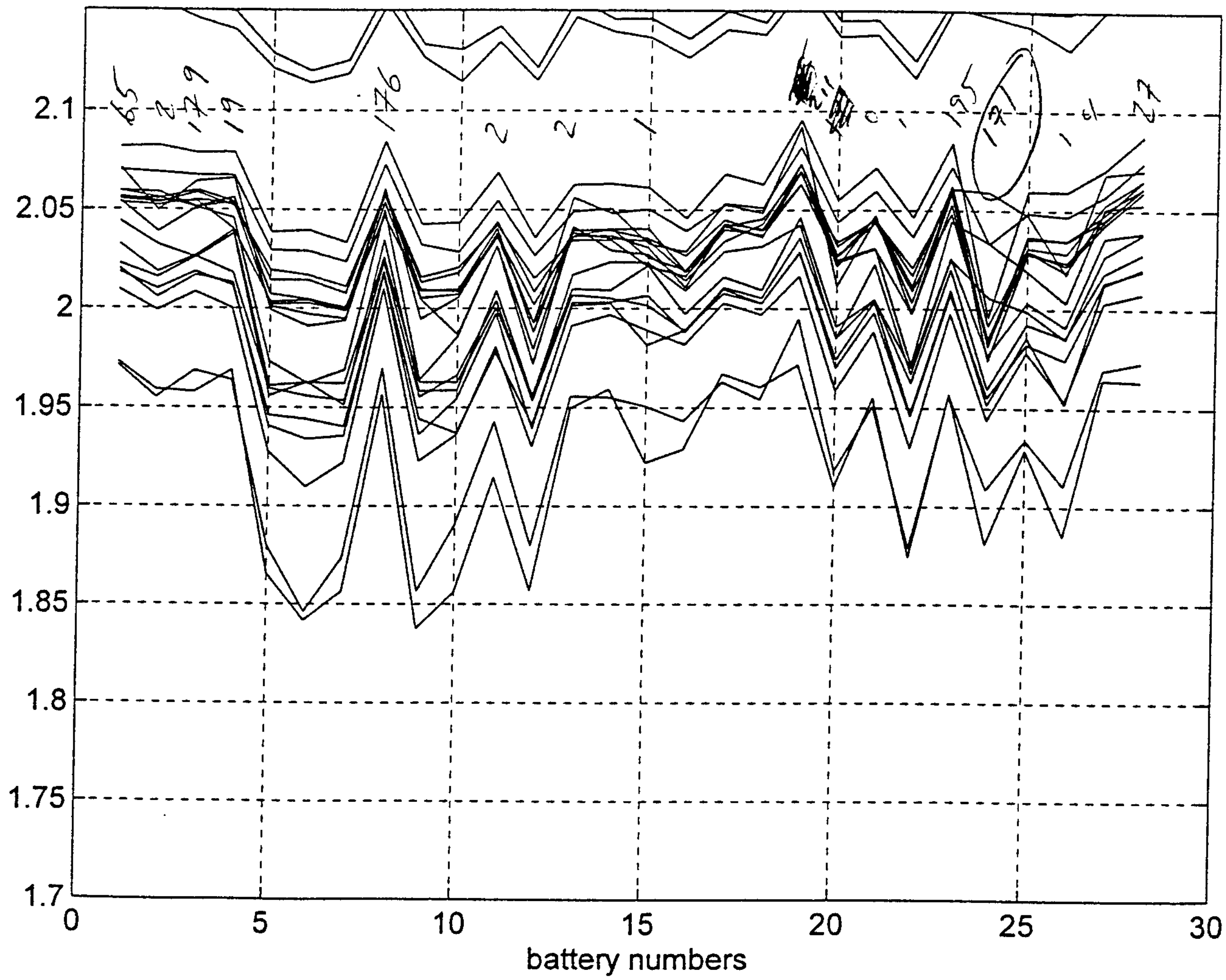
motor (o) and PCU (+) surface temperature
temperature (C)
time (sec)
52
50
48
46
44
42
40
38
36
34
0
500
1000
1500
2000
2500
3000
3500
4000
4500


PCU inlet (+) and outlet (o) coolant temperatures
60
55
50
45
40
35
temperature (C)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
time (sec)

cell voltages vs time for red car 1st run



cell voltages for 1st run of red car



AMERIGON EV4 SPECIFICATIONS

1.0 Vehicle Type

Passenger:	4
Type:	2 Door Hatch Back
Drive:	Front Wheel (Motor Direct Drive)

2.0 Physical Dimensions

Overall Length:	4,055 mm
Width:	1,675 mm
Height:	1,490 mm
Wheelbase:	2,485 mm
Track Front:	1,440 mm
Rear:	1,425 mm
Curb Weight:	1,400 kg (target) 3080 lb.
Weight Distribution:	50/50 With One Occupant

3.0 Clearances

Nominal Ground Clearance:	165 mm
Depth of pothole that can be cleared:	N.A.
Angle of ramp that can be cleared:	15° (Min.)
Approach Angle:	17° (Min.)
Departure Angle:	17° (Min.)
Height of curb that can be cleared:	N.A.
Front wheel to fender:	Amerigon recommends 30-40 mm (Samsung to verify)
Rear wheel to fender:	Amerigon recommends 30-40 mm (Samsung to verify)

4.0 Acceleration and Power

Acceleration:	0 to 400 m : 21.0 sec.
	0 to 100 kph : 16 sec.
Max. Speed:	More than 120 km/h
Hill Climbing Ability:	20% Min. at 15 kph for up to 5 Min.

Vehicle Specification Cont.

5.0 Range (Maintenance Free Lead Acid Battery)

Constant Speed (40 kph): More than 150 km
City Drive (Seoul): More than 60 km

6.0 Brake

Performance

60 to 0 kph:	43 m (max.)
30 to 0 kph:	18 m (max.)
Max. Speed to 0 kph:	75 m
Max. deceleration by brakes:	1g (max.)
Wet Pavement 60 to 0 kph:	52 m (max.)

Uniformity of braking deceleration

Spec to be developed by Samsung

Regeneration before brake application

Up to 0.3 g (Adjustable by controller) when acceleration pedal is fully lifted. Maximum regen must be adjustable by Samsung

Regenerative during brake application

Up to 0.6 g (Adjustable by controller) when accelerator is fully lifted. Maximum regen must be adjustable by Samsung

Response Time

Response Time from pedal application: 100 msec (max.)
Response Time from pedal release: 100 msec (max.)

Vehicle stability during braking

Must be able to maintain control under heavy braking.
Maximum 0.25 degree yaw.

Brake noise: Less than 50 db
Parking Brake: Meets FMVSS standards

7.0 Suspension

According to Basic Vehicle (Carry Over)

8.0 Tire and Wheel

Tire Size: 175/70/R13 - use Goodyear Invicta GLR
Temp.: T105/70/D14
Wheel Size: 5.5 J x 13

Vehicle Specification Cont.

9.0 Handling

Lateral Acceleration:	0.75 g (min.)
Degree of body roll:	3.5 degree max. at 0.5 g
	5.0 degree max. at max. accel.

10.0 Drive Train

Motor & Controller Type:	AC Induction
Power:	Satisfy Vehicle Performance
Energy Used:	Satisfy Driving Range
Transmission Type:	Single Speed
Final Drive:	Differential

11.0 Occupant Interaction

Display Supported:

Speedometer, Odometer, Turn Signal, Drive Engaged, Battery Level, Motor Temp., Lights for Brake, High Beam Low Energy Remaining, Seat Belt, Door Opening, Hood Opening, Refer to Ordering Spec.

12.0 Occupant Protection and Safety

Crash Worthiness:	Per Amerigon's Specification (Do not do vehicle tests, Simulation only)
Seat Belts:	Frame will be hard points for 3 points belts
High Voltage Isolation	Incorporated in controller

High Voltage Crash Disconnect

Battery Containment Requirements

Fail-safe models for loss of power brakes and steering revert to manual

Field of Vision:	According to Samsung SEV - III
Do not start*:	At Charging
	To prevent quick start, driver has to foot brake pedal when start

13.0 Durability

Warranty: 1 year 24,000 km (min.)

Target Life

Batteries:	1,000 Recharge cycle
Brakes:	120,000 km
Shock Absorbers:	150,000 km
Tire:	50,000 km

Battery pack replacement in field service possible

Vehicle Specification Cont.

14.0 Maintenance

Periodic maintenance: Check transmission oil
Check coolant

15.0 Environment

Temp. Range:	-20°C to 40°C Operating
	-40°C to 85°C Storage
Humidity Range:	0 to 100% Non-condensing
Rain on Chassis:	Must not damage or impair function
	Must not allow any current leakage from/into electrical system

16.0 Interfaces

Electrical Supply to Charger:	220 V 15 Amps. 60 Cycles
Test Equipment Interface:	RS 232 C
Tow hooks and towing provisions 2 in front, 1 in rear	
Vehicle ID Number:	Assigned by Samsung
Require warning level:	SAE standard on high voltage systems

Appendix 8: BEV Test Report

REVA
Testing Summary
Prepared by Amerigon Inc.

Table of Contents

Test Report
Prepared by Amerigon Inc.

I) VEHICLE TESTING

A) Test Vehicle Configuration

Vehicle Characteristics

Test load	136 kg (300 lb)
Curb Weight	645 kg (1,420 lb)
F/R Weight Ratio	40% / 60%
Wheel Base	1650 mm (65.0 in)
Track	1181 mm (46.5 in)
Length	2638 mm (103.9 in)
Width	1324 mm (52.1 in)
Height	1510 mm (59.4 in)
Ground Clearance	150 mm (5.9 in)
Turning Radius	3350 mm (131.9 in)
Tires	145/60R14
Wheels	3.5" x 14" Aluminum Alloy
Pressure	40 psi
Brakes	Four wheel dual circuit hydraulic drum brakes Integrated regenerative braking

Battery Characteristics

Battery Weight	240 kg (528 lb)
Battery Capacity (C-20)	2345AH
Battery Energy Density (C-20)	45 WH/kg
Battery Pack Voltage	48V nominal
Battery Pack Current	450A maximum
Charger	input (220 V, 12 A) output (48 V, 2KW)

Drivetrain Characteristics

Motor type	DC series
Power (peak)	12.7 KW
Power (continuous)	5 KW
Torque (max)	70 Nm
Transmission	7:1 single gear reduction directly coupled to motor drives rear wheels

B) Data Acquisition System

Testing was mostly conducted in-house at the Amerigon Inc. facility, in Monrovia California. Vehicle structure and electrical component testing was performed in-house. Vehicle drives were conducted at local tracks for dynamic and range tests. Two data acquisition systems were employed, one for speed sensing, and the other for electrical and thermal monitoring.

C) Test Description

1) Coastdown	-	Due to the lack of of long enough coast straight, coasting was done in 2 sequences, with deceleration rate in g's recorded between 3.3 to 6.6 kph and 37.3 to 43.9 kph. Taking lower figures was assumed to be the rolling drag coefficient, and the higher minus the lower figure to be the v^2 or the aero drag contribution.
Measured Quantities	-	Speed Time
Results	-	This tests verifies the aerodynamic and rolling resistance loss.
2) Battery Capacity	-	The vehicle is driven at a constant speed until the battery voltage drops to a specified end of charge voltage. The speed selected allow the vehicle to operate approximately 2 hours before the end of charge.
Measured Quantities	-	Vehicle speed Battery current Battery voltage Time
Results	-	This test determines the 2 hour capacity of the battery pack.
3) Full Throttle Acceleration	-	The vehicle is accelerated from 0 km/hr to 40 km/hr a under full throttle input. The test is conducted at 100% SOC, 80% SOC, 60% SOC and 40% SOC.

Measured Quantities	-	Time Vehicle speed
Results	-	The vehicle acceleration at various states of charge is determined.
4) Constant Speed	-	Vehicle is operated at constant speeds.
Measured Quantities	-	Vehicle speed Battery current Battery voltage
Results	-	The power required to propel the vehicle is calculated. Inefficiencies in the motor, controller, and transmission can be calculated.
5) Driving Range	-	The vehicle operator performs city driving and closed track constant speed driving.
Measured Quantities	-	Distance Battery voltage Battery current
Results	-	Vehicle range can be estimated
6) Battery Charging	-	The battery pack is charged from full discharge to 100% SOC using the on-board charger.
Measured Quantities	-	Battery current Battery voltage Time
Results	-	Battery charging energy.

C) Test Results Summary

1) Coastdown

The rolling drag coefficient was measured between .0075 and .0095 on two vehicles and two surfaces. The aero drag contribution at 40 kph was .0090 times an effective mass of 1720 lbs indicating a CdA of about 10.0.

2) Battery Capacity

The REVA was tested at a constant speed discharge to determine the battery capacity at approximately the 2 hour discharge rate. For this test the vehicle was operated at a constant speed which corresponded to the manufacture suggested 2 hour discharge current of 80 amps. The vehicle was held at this speed until the battery voltage dropped to 43V. This pack voltage corresponds to a cell voltage of 1.79V, as determined by BCI tests.

Battery capacity at this speed was measured to be 160 amp hours or 7400 watt hours. This value was used as the battery capacity baseline and other states of charge were determined from this value. Figure 1 indicates the amount of energy removed from a fully charged battery pack to conduct lower state of charge tests.

Figure 1 - Battery Capacity at Various SOC

% SOC	Energy Remaining At C2	Energy Removed from Fully Charged Pack
100 % SOC	7400 watt hours	0 watt hours
80 % SOC	5920 watt hours	1480 watt hours
50 % SOC	3700 watt hours	3700 watt hours

3) Full Throttle Acceleration

The vehicle was accelerated at full throttle for battery states of charge of 100% SOC, 80% SOC, 60% SOC, and 40% SOC. The results show (figure 2) that less power is available from the batteries as the battery state of charge decreases. This decrease in power is related to lead acid batteries' tendency to have a greater voltage drop at lower states of charge.

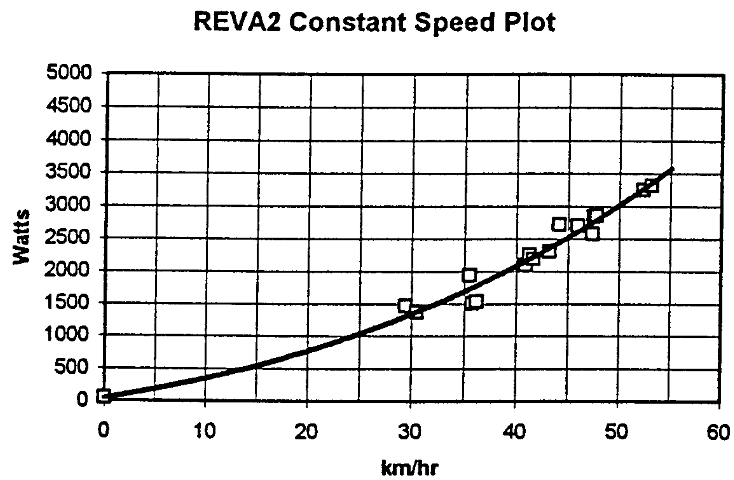
Figure 2 - Running Chassis Acceleration

0 - 48 kph Run	100% SOC	80% SOC	60% SOC	40% SOC
1	11.05 sec.	11.29 sec.	12.30 sec.	13.37 sec.
2	11.03 sec.	11.16 sec.	11.70 sec.	12.71 sec.

4) Constant Speed

For the constant speed tests, the vehicle was operated at a constant speed while the power out of the battery was recorded. The power required at the vehicle wheels is also recorded. With these two power values the energy lost in the vehicle drive system can be determined. Figure 3 shows the power consumption versus vehicle speed.

Figure 3



5) Driving Range

The range of the REVA was tested at a constant speed of 47 kph was 124.3 km. City driving range was measured at 78.9 km. This corresponds well to a simulated driving range of 80km.

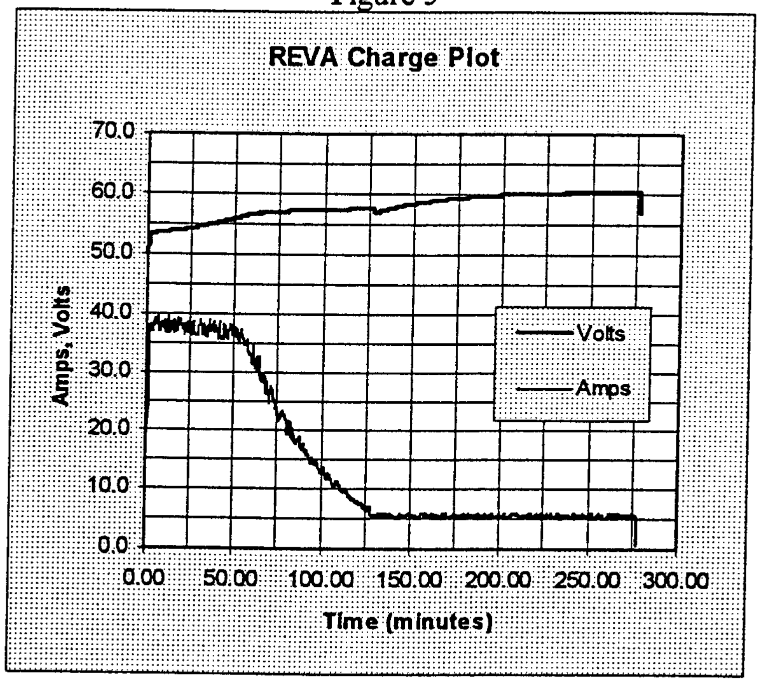
6) Battery Charging

The battery charging system was tested to determine the efficiency of the batteries, as well as the efficiency of the charger. After the batteries were completely discharged, the battery capacity was determined. Charger supply power was a standard 220 VAC 15 amp wall outlet. Battery energy was measured during battery charging. With these two measurements the battery charging efficiency could be calculated. Figure 4 indicates the measured energy capacity and battery input energy values for the charging test. Figure 5 is a sample charge plot.

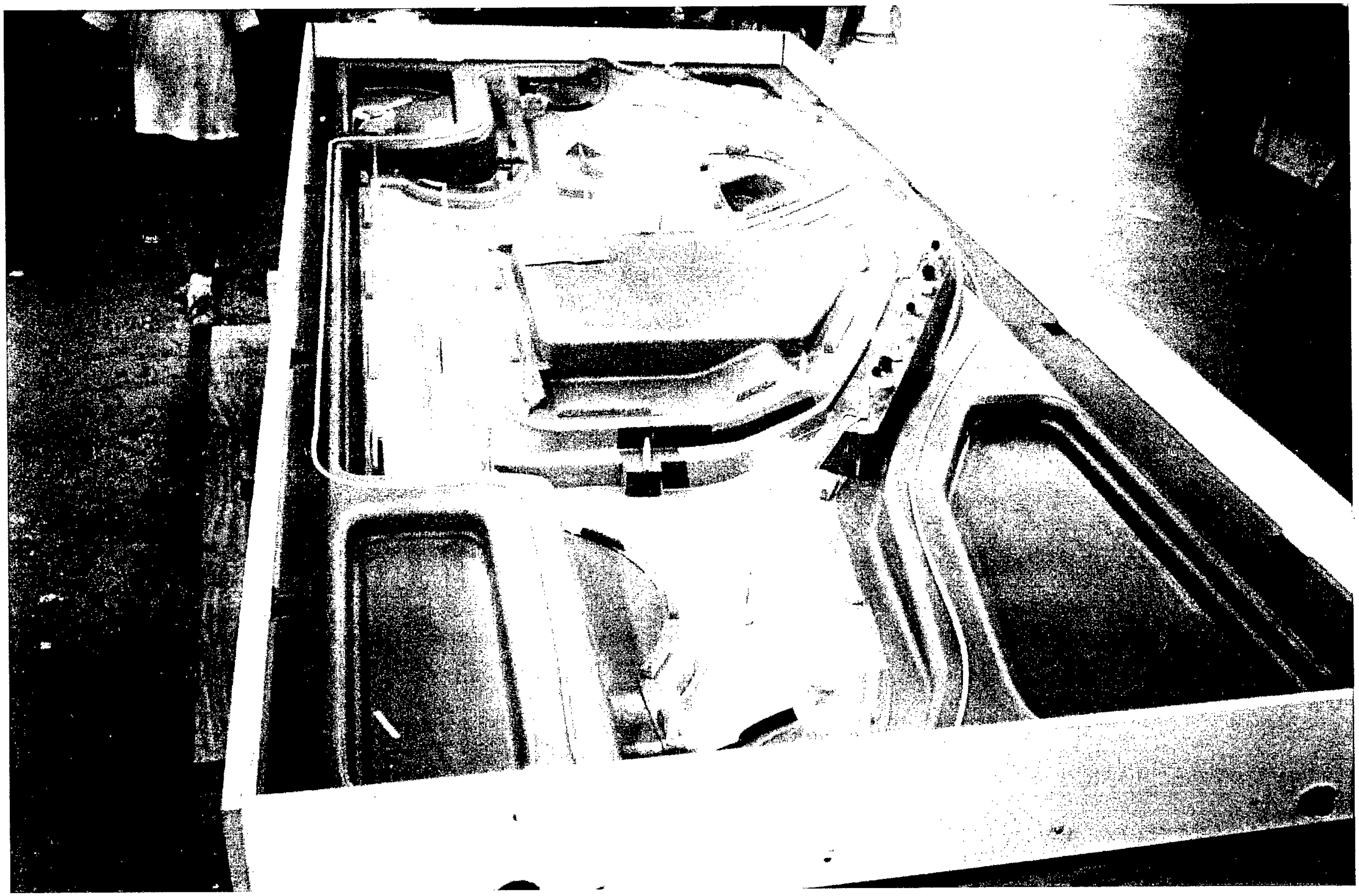
Figure 4 - Charging Data

Battery Capacity (c2 rate)	7400 kW hrs
Energy Into Batteries	8010 kW hrs

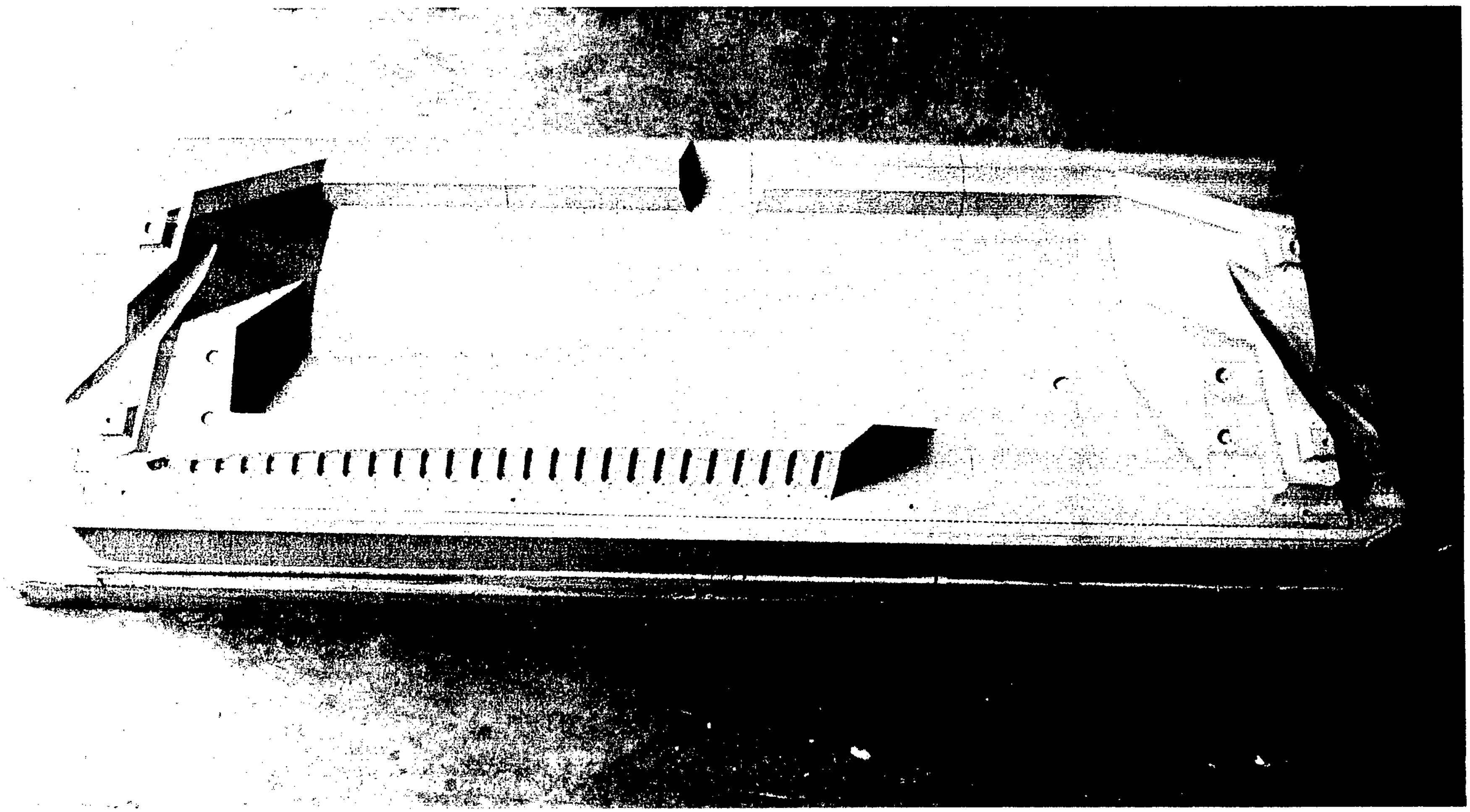
Figure 5



Appendix 9: Photos of EV4 and BEV Tooling



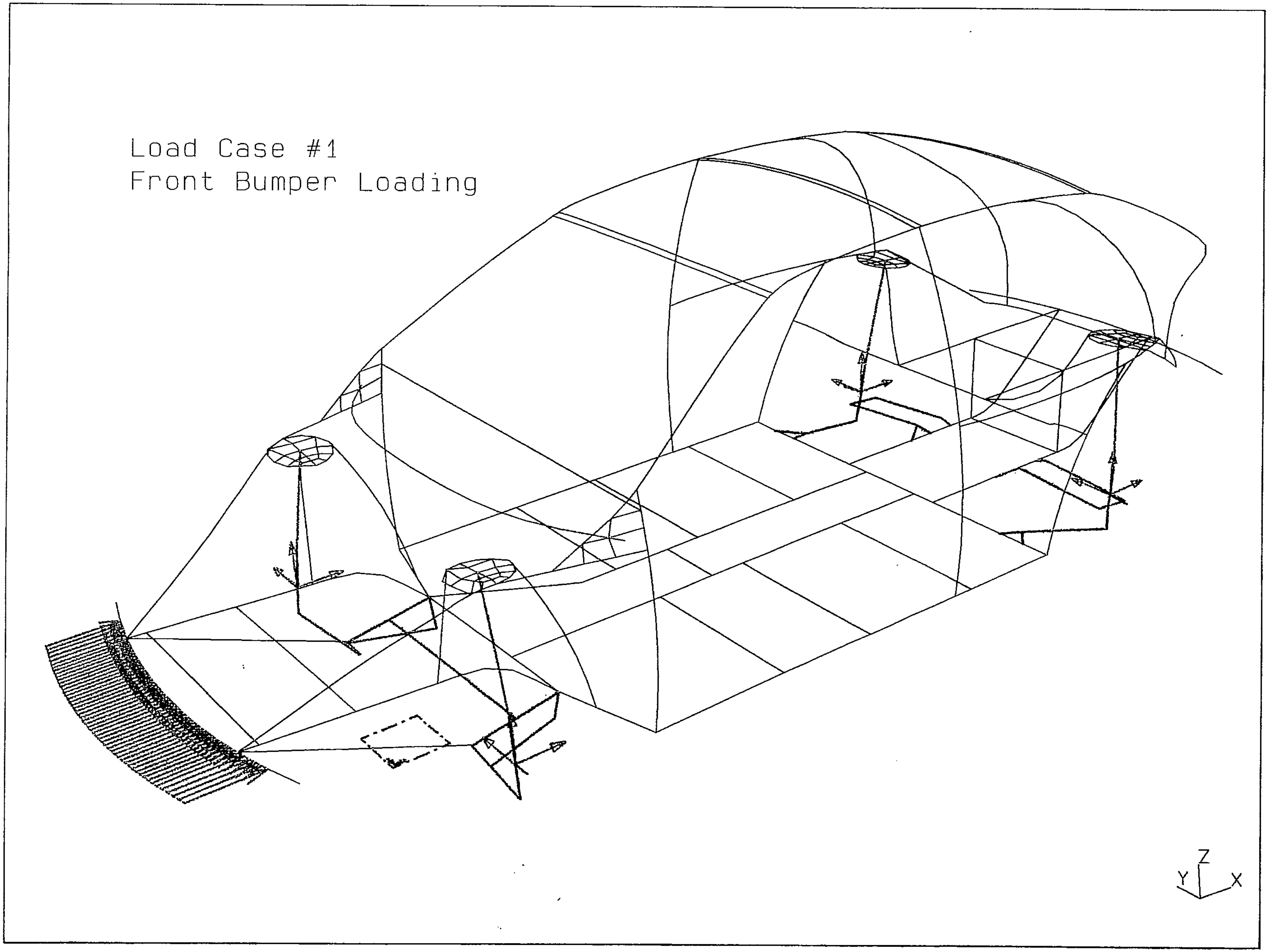
RTM Body Side Tool (part length is 3640mm, height 1300mm)



BEV Cowl Forming Die

Appendix 10: Finite Element Analysis of EV4 Chassis

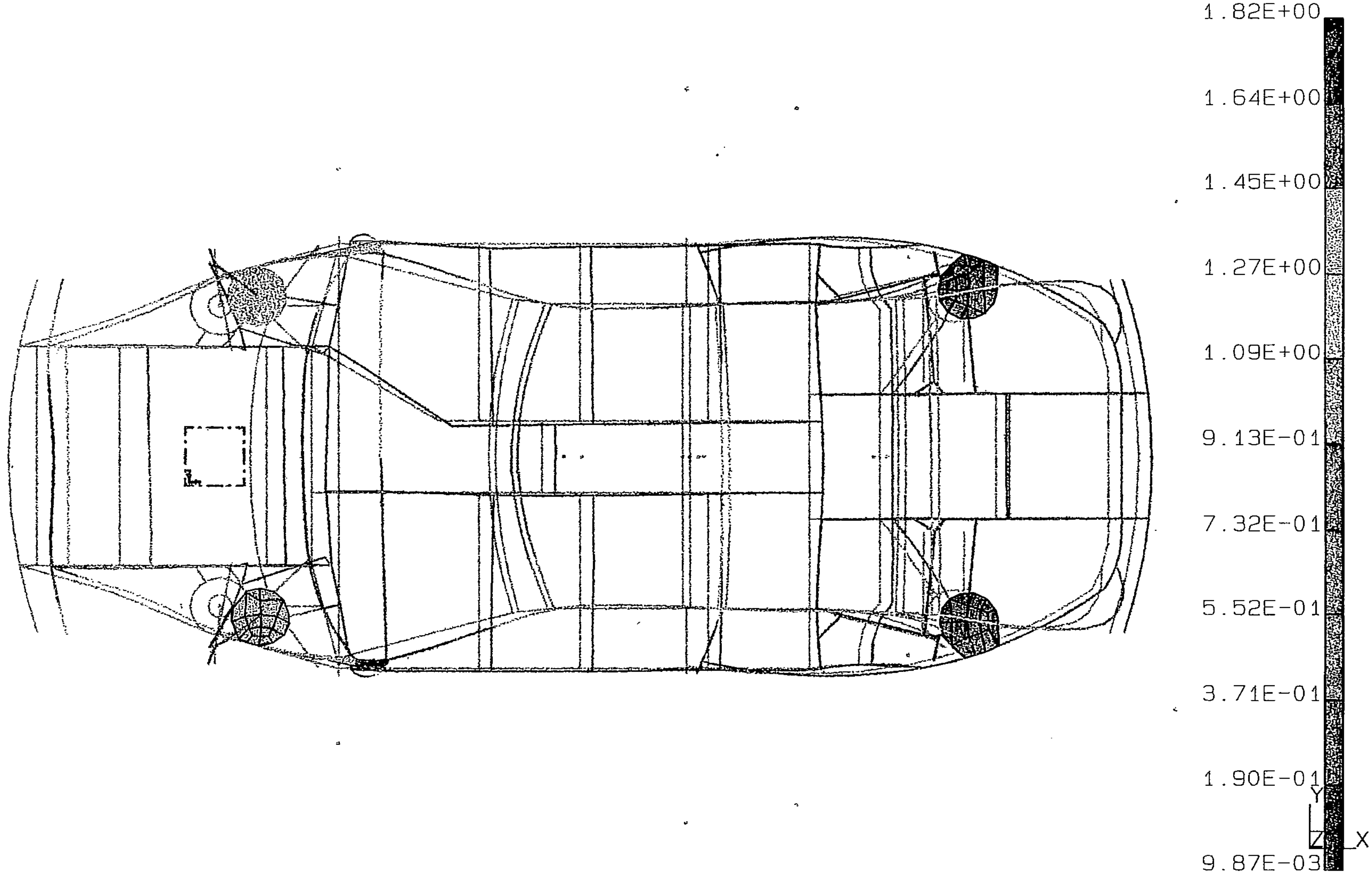
Load Case #1
Front Bumper Loading



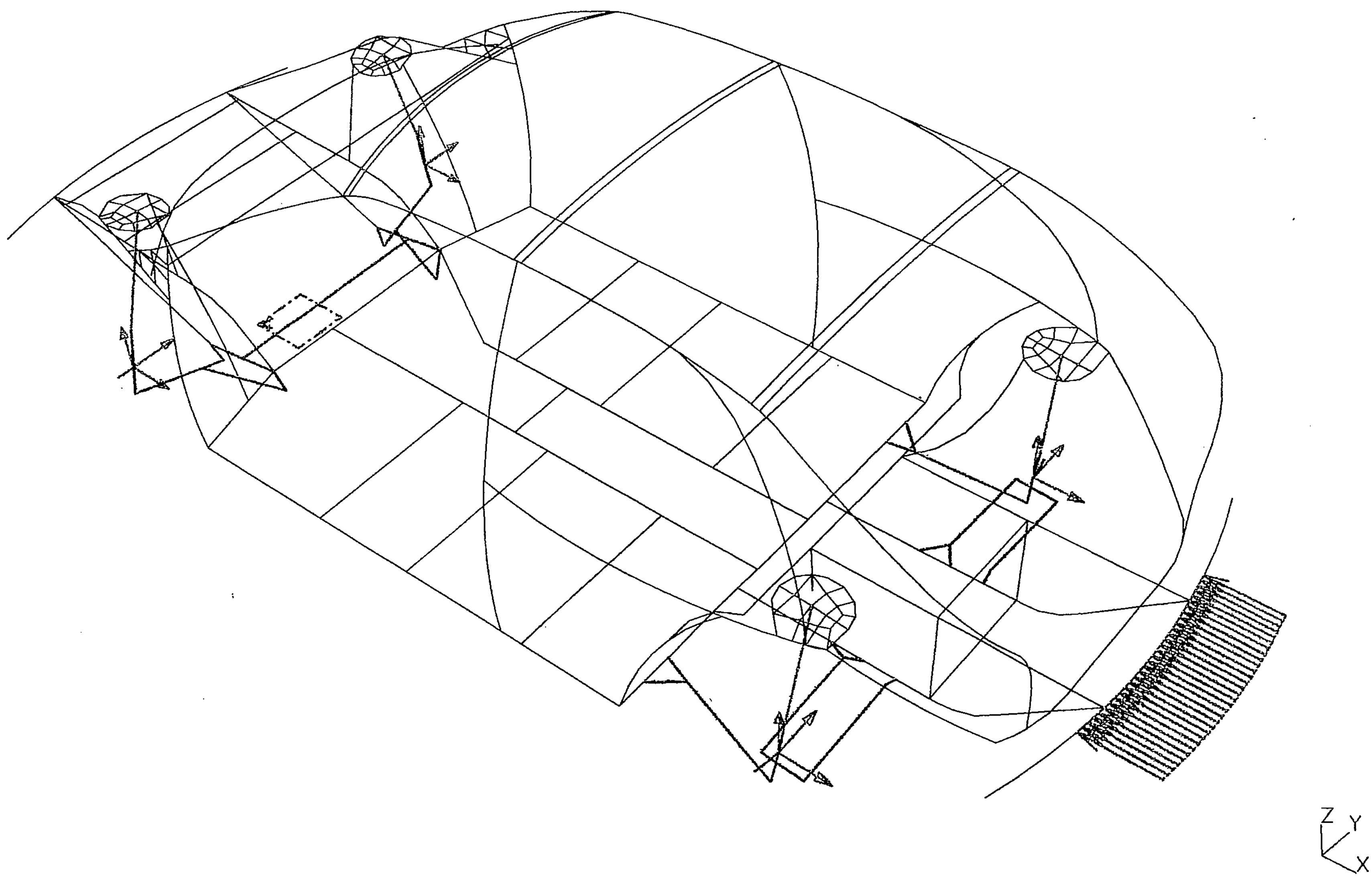
/users/cain/models/ev4-fea.mf1

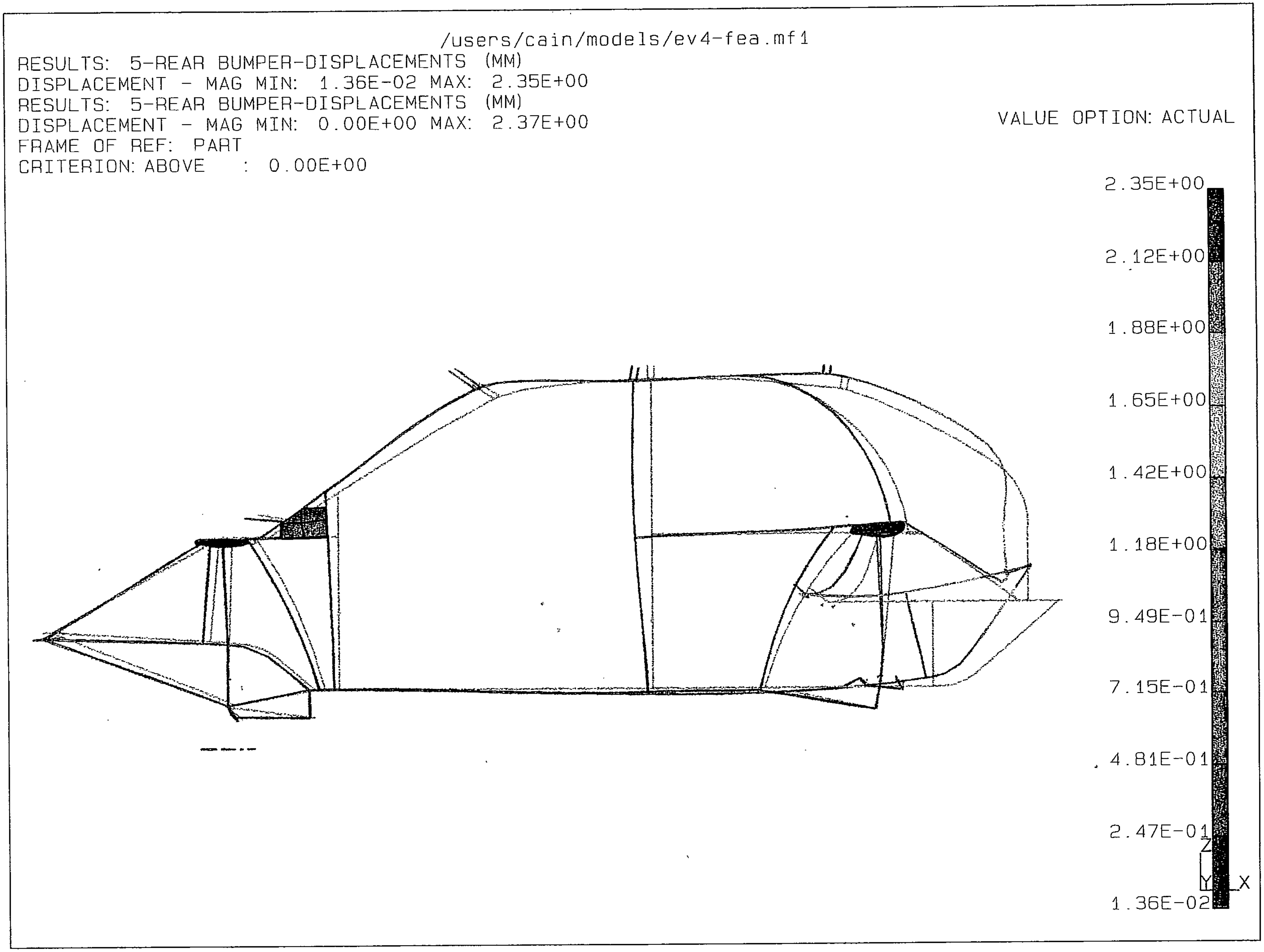
RESULTS: 3-FRONT BUMPER-DISPLACEMENTS (MM)
DISPLACEMENT - MAG MIN: 9.87E-03 MAX: 1.82E+00
RESULTS: 3-FRONT BUMPER-DISPLACEMENTS (MM)
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 1.83E+00
FRAME OF REF: PART
CRITERION: ABOVE : 0.00E+00

VALUE OPTION: ACTUAL

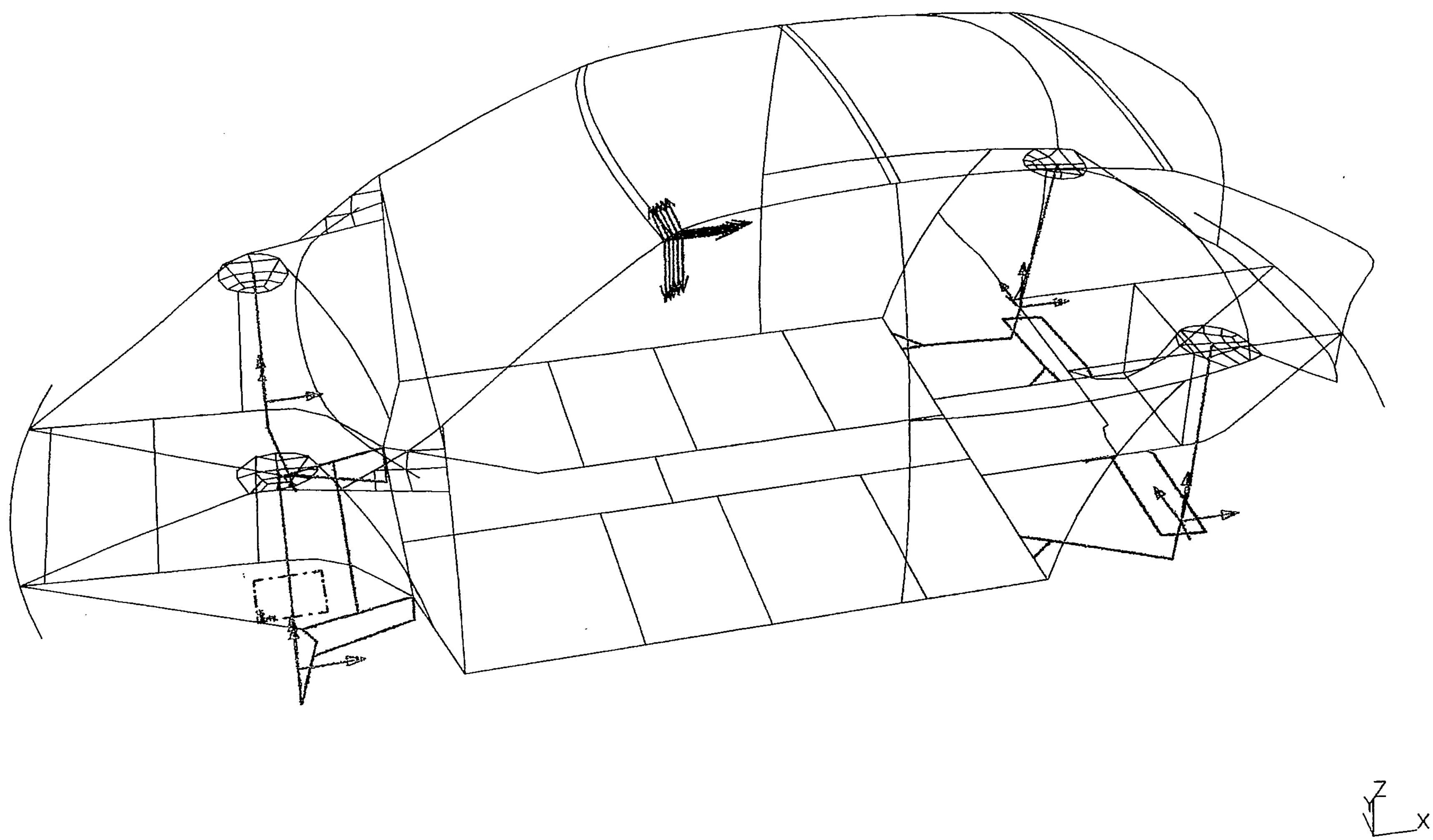


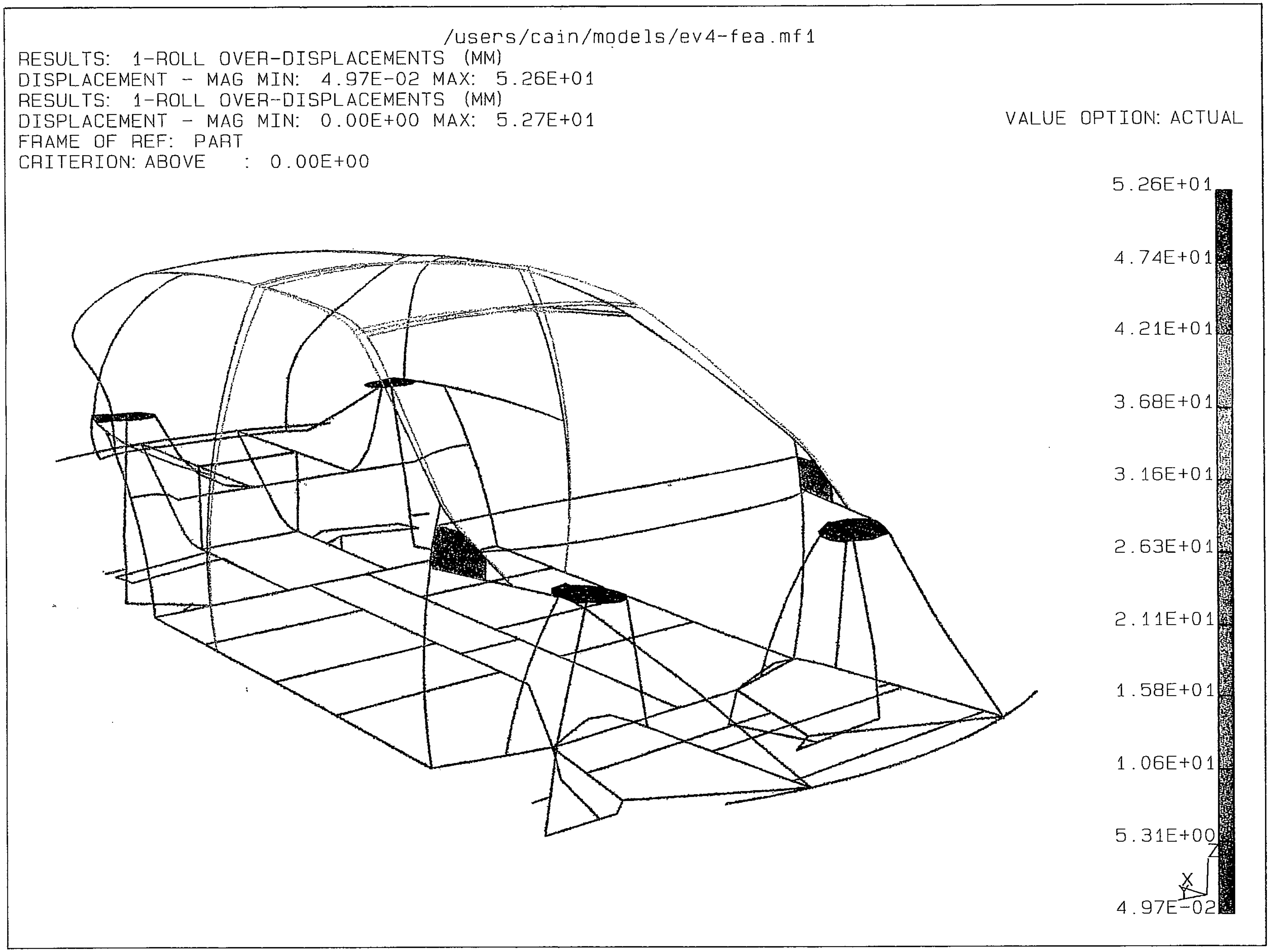
Load Case #2
Rear Bumper Loading




/users/cain/models/ev4-fea.mf1
RESULTS: 5-REAR BUMPER-DISPLACEMENTS (MM)
DISPLACEMENT - MAG MIN: 1.36E-02 MAX: 2.35E+00
RESULTS: 5-REAR BUMPER-DISPLACEMENTS (MM)
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 2.37E+00
FRAME OF REF: PART
CRITERION: ABOVE : 0.00E+00
VALUE OPTION: ACTUAL
2.35E+00
2.12E+00
1.88E+00
1.65E+00
1.42E+00
1.18E+00
9.49E-01
7.15E-01
4.81E-01
2.47E-01
1.36E-02
Z
Y
X

Load Case #3
Roll Over



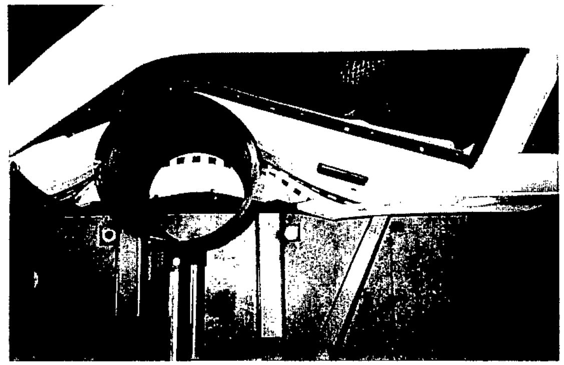


/users/cain/models/ev4-fea.mf1
RESULTS: 1-ROLL OVER-DISPLACEMENTS (MM)
DISPLACEMENT - MAG MIN: 4.97E-02 MAX: 5.26E+01
RESULTS: 1-ROLL OVER-DISPLACEMENTS (MM)
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 5.27E+01
FRAME OF REF: PART
CRITERION: ABOVE : 0.00E+00
VALUE OPTION: ACTUAL
5.26E+01
4.74E+01
4.21E+01
3.68E+01
3.16E+01
2.63E+01
2.11E+01
1.58E+01
1.06E+01
5.31E+00
4.97E-02
Z
X
Y

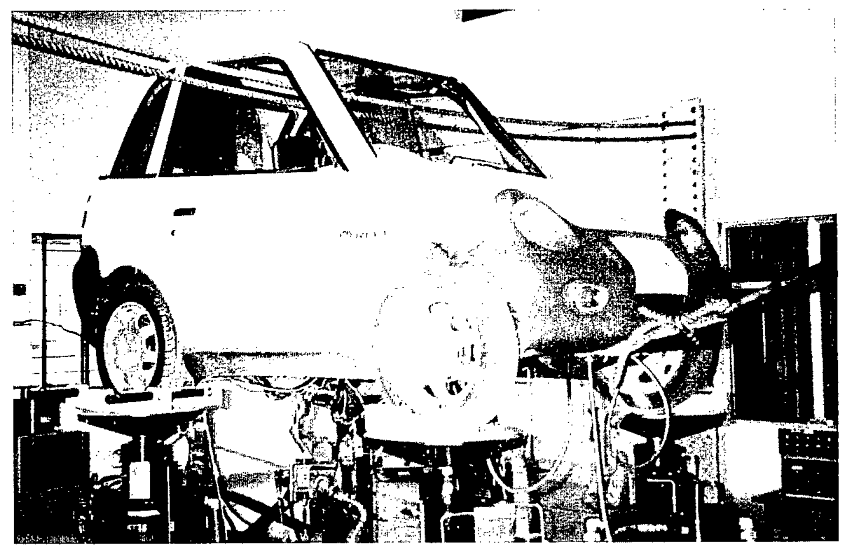
Appendix 11: Photos of BEV Testing

REVA Electric Vehicle Undergoing Durability Testing

Rough Road Durability Testing

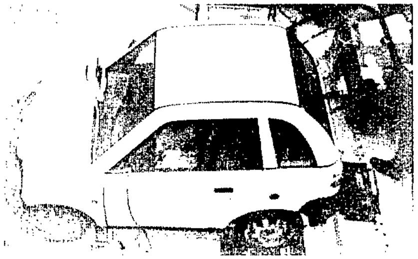


REVA Passes Indian Side-Impact Regulations



Four Post Shaker Testing

REVA Testing



Dynamometer Testing
at CARB, USA

Body Panel
Weathering Testing

Vehicle Calibration for
Vehicle Performance Testing

Stability Testing

Appendix 12: Baseline Testing of Running Chassis

Calstart Running Chassis
Testing Summary
Prepared by Amerigon Inc.

I) VEHICLE DYNAMOMETER TESTING

A) Test Vehicle Configuration

Vehicle Characteristics

Wheel base:	2.7 m (105 in.)
Wheel track front:	1.5 m (59.5 in.)
Wheel track rear:	1.4 m (55.5 in.)
Vehicle weight:	1201 kg (2647 lb.)
Weight distribution:	51% front - 49% rear
Vehicle height:	1.44 m (57 in.)
Vehicle length:	4.4m (172 in.)
Tire:	Pirelli 175 / 60 R 16 Prototype low rolling resistance electric vehicle tire
Tire diameter:	622 mm
Tire width:	176 mm
Tire pressure:	2 bar (30 psi)
Suspension front:	BMW double pivot McPherson strut
Suspension rear:	BMW trailing C-link
Steering:	BMW rack and pinion power assisted from velocity controlled 312 V DC motor
Brakes front:	Vacuum assisted BMW disk
Brakes rear:	Vacuum assisted BMW drum
Water cooling pump:	12 V
Vacuum pump:	12 V

Battery Characteristics

Battery type:	Trojan battery DC78 lead-acid
Number of batteries:	26 12 V
Configuration:	Series configuration, 6 batteries in front and rear pack 14 batteries in center pack
Battery pack weight:	460 kg (1014 lb.)
Battery pack voltage:	312 V nominal
Battery rating:	42 Ah @C2
Charging voltage:	110 V AC or 220 V AC
Charge current:	single phase 15 A

Drivetrain Characteristics

Motor type:	Hughes Power Control System; three-phase, four-pole AC induction
Controller type:	Hughes Power Control System; three-phase, four-pole AC induction
Motor weight:	60 kg (132 lb.)
Controller / charger weight:	30 kg (66 lb.)
Power peak:	50 kW
Power continuous:	20 kW
Torque peak:	160 Nm
Torque continuous:	53 Nm
Maximum speed:	9000 rpm
Cooling:	50 - 50 mixture of ethylene glycol and water
Transmission:	Front wheel drive, double reduction, ring and pinion type differential
Gear ratio:	7.95 : 1

B) Data Acquisition System

Testing was conducted at The State of California Air Resources Board (CARB) Mobile Source Division in El Monte, California. CARB offered dynamometer testing time, as well as engineering time to preform the tests. Three data acquisition systems (DAS) were used through out the testing. These consisted of the standard dynamometer equipment, CARB's Versatile Data Acquisition System (VDAS), and the Dolphin system. The primary data was taken with the standard dynamometer equipment while data was verified with the other two systems.

C) Test Description

1) Coastdown - Vehicle is allowed to decelerate from 60 mph to 0 mph under the dynamometer load

Measured Quantities - Speed
Time

Results - This tests verifies that a vehicle on the dynamometer behaves like a

vehicle on a road

2) Battery Capacity - The vehicle is driven at a constant speed
until the battery voltage drops to a specified
end of charge voltage. The speed
selected allow the vehicle to operate approximately
2 hours before the end of charge.

Measured Quantities - Vehicle speed
Battery current
Battery voltage
Time

Results - This test determines the 2 hour capacity of the battery pack. This value is used to determine the 80% SOC and 50% SOC battery states.

3) Full Throttle Acceleration - The vehicle is accelerated from 0 mph to 60 mph a under full throttle input. The test is conducted at 100% SOC, 80% SOC, and 50% SOC.

Measured Quantities - Time
Vehicle speed

Results - The vehicle acceleration at various states of charge is determined.

4) Constant Speed - Vehicle is operated at constant speeds.

Measured Quantities - Vehicle speed
Battery current
Battery voltage

Results - The power required to propel the vehicle is calculated. Inefficiencies in the motor, controller, and transmission can be calculated.

5) Driving Range - The vehicle operator follows 2 UDDS schedules and then follows 2 HWFET driving schedules.

Measured Quantities - Distance
Battery voltage
Battery current

Results - Vehicle range can be estimated

6) Battery Charging - The battery pack is charged from full discharge to 100% SOC using the on-board charger.

Measured Quantities - Battery current
Battery voltage
AC source current
AC source voltage

Results - Battery and charger efficiency can be calculated.

C) Test Results Summary

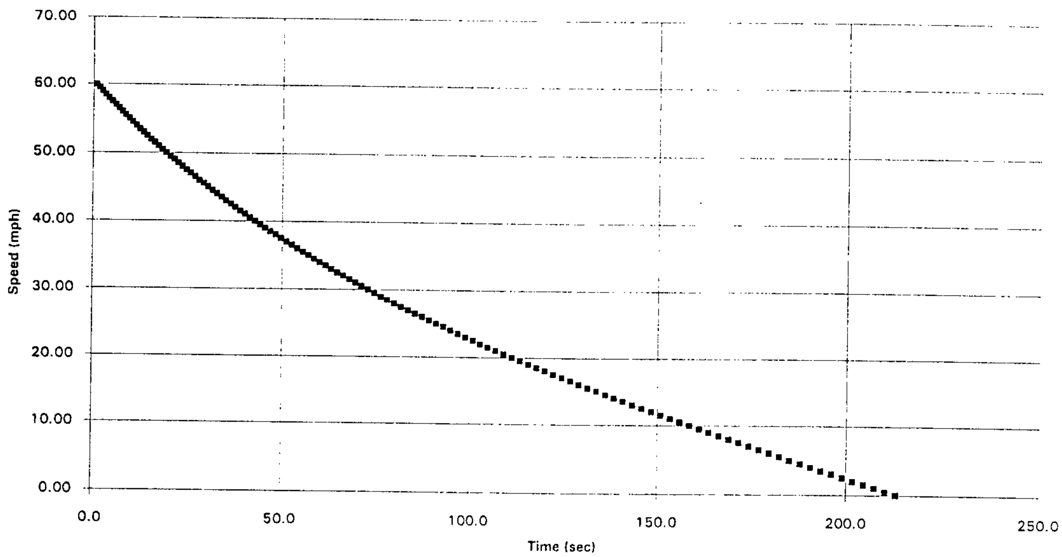
1) Coastdown

To test on a stationary dynamometer, input data consisting of vehicle loads is required. These inputs allow the dynamometer to duplicate the loads the vehicle experiences while driving. The traditional method of determining these input loads is to conduct vehicle coastdown test. A vehicle is allow to decelerate from a speed of approximately 60 mph to 0 mph while in neutral. Speed is recorded as a function of time so that the retarding forces of rolling resistance and aerodynamic drag can be calculated. These forces are then input into the dynamometer and the dynamometer will simulate the actual driving loads.

The CALSTART Running Chassis is a prototype spaceframe design. This spaceframe can accommodate various body shapes for different customers. However, the prototype tested does not have an exterior body. Because there is no body, traditional coastdown testing would not offer the appropriate driving loads. Therefore, road loads were developed using a computer simulation of the Running Chassis with a large four-door, sedan body. The simulated coastdown data (figure 1) was input into the dynamometer and used for dynamometer calibration.

The dynamometer calibration was verified by having the dynamometer to accelerate the vehicle to 60 mph and then allowing the vehicle to coast to a stop. The speed and time data was compared to the input values and the dynamometer was adjusted to correct for differences. This process continued until the dynamometer values and input values were within the appropriate tolerances.

Figure 1 - Simulated Coastdown



2) Battery Capacity

The Running Chassis was tested at a constant speed discharge to determine the battery capacity at approximately the 2 hour discharge rate. For this test the vehicle was operated at a constant 45 mph, a speed which corresponded to the manufacture suggested 2 hour discharge current of 22 amps. The vehicle was held at this speed until the battery voltage dropped to 273V. This pack voltage corresponds to a cell voltage of 1.75V, which was determined to be a safe end of charge voltage. Taking the batteries to a lower voltage is possible; however, some battery damage would occur and battery life would be decreased.

At a constant speed of 45 mph the vehicle operated above 273V for 7050 seconds. This was approximately the 2 hour discharge that was desired. Battery capacity at this speed was measured to be 41.6 amp hours or 12800 watt hours. This value was used as the battery capacity baseline and other states of charge were determined from this value. Figure 2 indicates the amount of energy removed from a fully charged battery pack to conduct lower state of charge tests.

Figure 2 - Battery Capacity at Various SOC

% SOC	Energy Remaining At C2	Energy Removed from Fully Charged Pack

100 % SOC	12800 watt hours	0 watt hours
80 % SOC	10240 watt hours	2560 watt hours
50 % SOC	6400 watt hours	6400 watt hours

3) Full Throttle Acceleration

The vehicle was accelerated at full throttle for battery states of charge of 100% SOC, 80% SOC, and 50% SOC. The results show (figure 3) that less power is available from the batteries as the battery state of charge decreases. This decrease in power is related to lead acid batteries' tendency to have a greater voltage drop at lower states of charge.

Figure 3 - Running Chassis Acceleration

0 - 60 mph Run Number	100% SOC	80% SOC	50% SOC
1	17.27 sec.	17.76 sec.	21.83 sec.
2	17.13 sec.	18.19 sec.	25.28 sec.

4) Constant Speed

For the constant speed tests, the vehicle was operated at a constant speed while the power out of the battery was recorded (Figure 4). The power required at the vehicle wheels is also recorded. With these two power values the energy lost in the vehicle drive system can be determined. The power lost indicates the motor, controller, and transmission system efficiency (Figure 5).

Figure 4 - Constant Speed Power Requirements

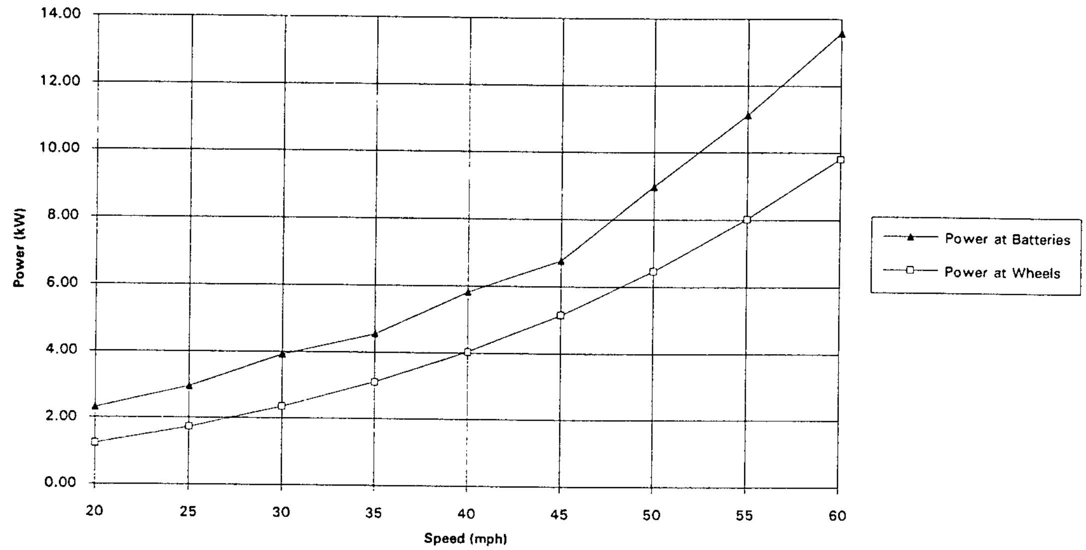
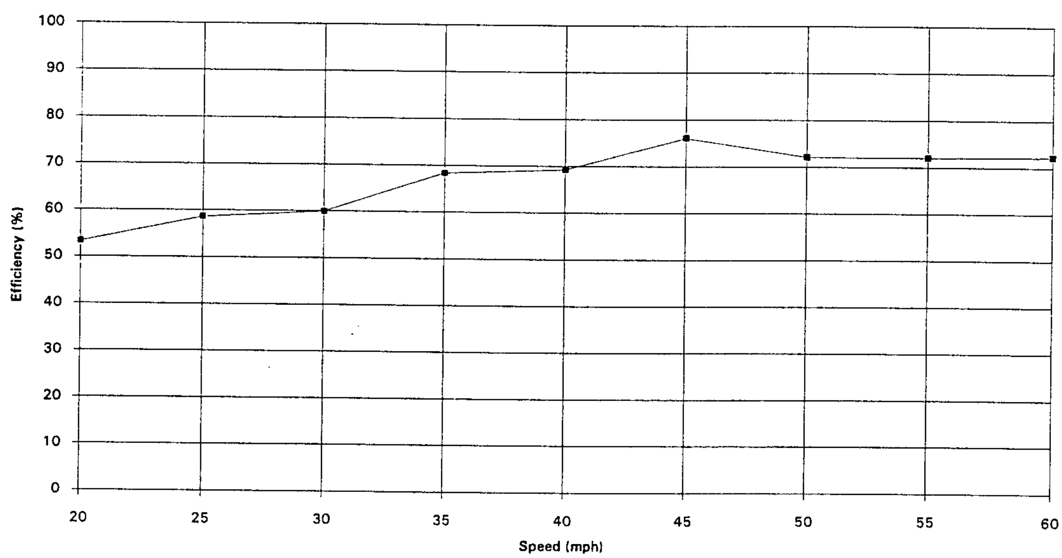


Figure 5 - Drive System Efficiency



5) Driving Range

The range of the Running Chassis was tested on two driving scheduled, the UDDS and the HWFET. These schedules are standard velocity versus time profiles for vehicle driving. For this test a operator sat in the vehicle and operated the accelerator pedal. The operator watched a video screen which graphically indicated the actual vehicle speed and the appropriate speed for the given cycle. The operator continually manipulated the accelerator pedal to assure the vehicle speed was the same as the desired schedule speed. This continued for 2 schedules. The distances traveled as well as vehicle performance are indicated in figure 6. The range estimate is derived from the energy required for each schedule cycles and the data collected from the battery capacity test.

Figure 6 - Driving Range

Schedules	Two UDDS Schedules	Two HWFET
Distance Driven	14.91 miles	20.53 miles
Gross Energy Out	3.79 kW hrs	4.16 kW hrs
Net Energy Out	2.86 kW hrs	3.83 kW hrs
Percent Regen	24 %	8 %
Energy / Mile	192 W hr / mile	187 W hr / mile
Estimated Range	64.3 miles	66.0 miles

6) Battery Charging

The battery charging system was tested to determine the efficiency of the batteries, as well as the efficiency of the charger. After the batteries were completely discharged during the battery capacity test they were fully charged while battery power and AC supply power were monitored. The supply power was a standard 220V ac 15 amp wall outlet. Power was measured before the charger, and before the batteries. With these two measurements the efficiency of the charger could be determined. With the tested battery capacity and the power going into the batteries, the charge efficiency of the batteries could be calculated. Figure 7 indicate the measured and calculated values for the charging test.

Figure 7 - Charging Data

Battery Capacity (c2 rate)	12.34 kW hrs
Energy Into Batteries	16.4 kW hrs
Battery Efficiency	75 %
AC Source Output Energy	26.29 kW hrs
Charger Efficiency	62 %

II) TRANSMISSION SYSTEM TESTING

A) Test Vehicle Configuration

Gearbox: Change	Modified Speedway Engineering Mini-stock Quick
Ring and pinion gears:	Speedway Engineering 4.11:1 ratio and 5.38 ratio
Change gears:	National hobbed, spur gears 16/28 teeth Boston hobbed, helical gears 12/24 teeth Speedway ground, spur gears 20/40 teeth
Motor type: pole AC	Hughes Power Control System; three-phase, four- induction
Controller type: pole AC	Hughes Power Control System; three-phase, four- induction

B) Data Acquisition System

Noise testing on the running chassis was conducted on a bench top. This assured the isolation due to noise from gears and eliminated the rolling noise of the tires. The gearbox and motor system were removed from the vehicle; however, they were powered by the batteries and controller which remained mounted to the vehicle. Testing occurred with minimal transmission loading. No load conditions resulted in a louder gearbox because of gear chatter that did not exist when the transmission was loaded.

Noise measurements occurred 2 feet in front of the gearbox. These were taken with an Extech 407703 sound level meter. The background noise was not significant and is not included in the attached data.

C) Test Description

1) Ring and Pinion Noise Test - Motor is rotated at various speed while noise energy measurements are taken. The ring and pinion gear ratios are changed for each test.

Measured Quantities - Motor speed
Noise energy

Results - This test isolates the ring and pinion gear ratio's effect on noise.

2) Change Gear Noise Test - Motor is rotated at various speeds while noise energy measurements are taken. The gearbox change gears are changed for each test.

Measured Quantities - Motor speed
Noise energy

Results - This test isolates the change gear ratio's and manufacturing quality's effect on noise.

3) Transmission Fluid Additive - Motor is rotated at various speeds while noise energy measurements are taken. Transmission fluid additive is added and compared to no addictive.

Measured Quantities	-	Motor speed Noise energy
Results	-	This test isolated the effect of transmission additives on noise.

4) Component Efficiency - Motor is rotated at various speeds with no gears, as well as with change gears to identify the individual contributions to energy loss.

Measured Quantities	-	Motor speed Battery current Battery voltage
Results	-	This test isolated the seal and gear energy losses.

D) Test Results Summary

Because electric motors produce very little noise, electric vehicle noise is largely effected by road and gearbox sounds. In an effort to reduce the vehicle noise in the Running Chassis the gearbox was tested for component noise contribution and noise reduction techniques were tested. The Running Chassis gearbox consists of a ring and pinion differential section and a single reduction change gear section. The differential section is similar to the rear end differential of a standard rear wheel drive vehicle. A ring and pinion gear drives a differential to power the wheels. The change gear section contain a single reduction set of gears. These are mounted on shafts that have a quick access cover. This cover allows the change gears to be quickly changed for testing purposes. As part of the transmission testing these two sections were individually tested for noise contribution. Transmission lubrication fluid was also investigated and tested for possible noise reductions.

1) Ring and Pinion Noise Test

The effect of ring and pinion gear ratio was tested by measuring the gear box noise at various motor speed for different ring and pinion ratios. The tests indicated that the larger gear rotation is quieter (Figure 8). This was expected because the larger ratio allows more surface area for gear contact. This larger area eliminates some of the chatter as the gear teeth come in contact with each other.

Figure 8 - Ring and Pinion Noise Tests		
Motor Input	4.11:1 Ratio	5.38 Ratio
1000 RPM	80 db	80 db
2000 RPM	87 db	85 db
3000 RPM	92 db	88 db
4000 RPM	95 db	93 db
5000 RPM	98 db	96 db
7500 RPM	103 db	99 db

2) Change Gear Noise Test

To test the noise contribution of the change gear section the motor was operated at various speeds for an assortment of change gears. The gears tested consisted of a set of National brand hobbed, spur gears; a set of Boston brand cut, helical gears; and a set of Speedway brand ground, spur gears. Figure 9 indicates the measured values for various motor speeds.

Figure 9 - Change Gear Noise Tests			
Motor Input	Hobbed, Spur Gear	Cut, Helical Gear	Ground, Spur Gears
1000 RPM	80 db	76 db	80 db
2000 RPM	85 db	80 db	87 db
3000 RPM	88 db	88 db	92 db
4000 RPM	93 db	94 db	98 db
5000 RPM	96 db	94 db	101 db

3) Lubricant Additive Test

The final noise test conducted on the gearbox tested commercially available transmission fluid additives. To conduct this test baseline measurements were taken with 80 weight gear oil. A second set of measurements was then taken with a commercial additive added to the gear oil. The commercial additive did reduce the noise. The noise reduction can be attributed to higher viscosity fluid. Figure 10 summarizes the results.

Figure 10 - Lubricant Additive Test		
Motor Input	No Additive	Additive
1000 RPM	80 db	76 db
2000 RPM	85 db	80 db

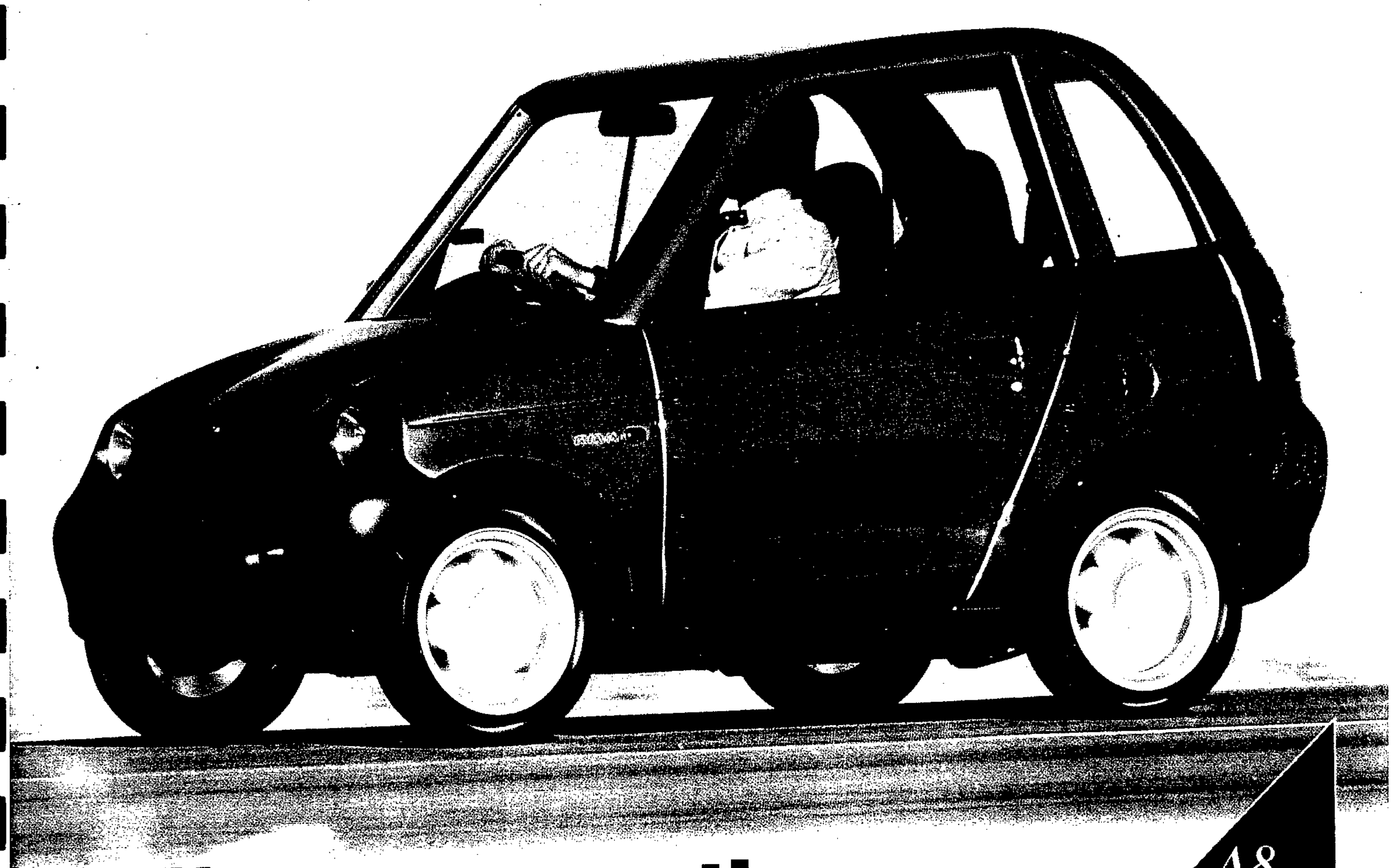
3000 RPM	88 db	88 db
4000 RPM	93 db	94 db
5000 RPM	96 db	94 db

Appendix 13: BEV (REVA) Press Releases

MOTORINDIA

41st year of publication | January 1997 | Rs. 20

DIMS Special



New generation REVA electric car

A8 Audi Poster FREE

AL's MASSIVE PROJECT • VEHICLE SALEs falling

January 1997 Rs.15

TECHNO WORLD

The features magazine in science and technology

A review on 'Twister' - the movie

Aarevah!

An exclusive feature on India's first battery powered car

- Fourth WWW user survey
- Sukhoi - 30 joins IAF
- Solutions to the Year 2000 problem

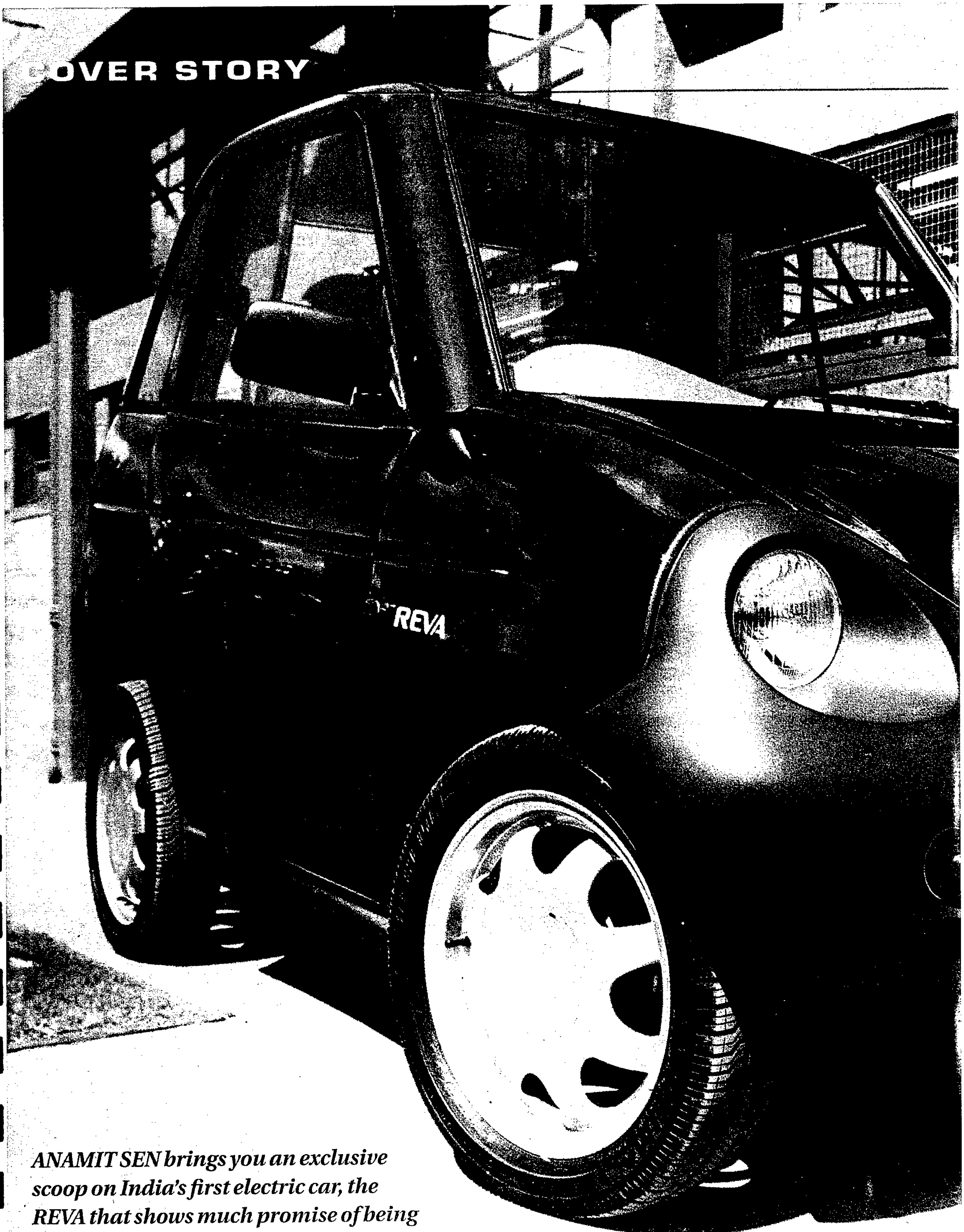
FREE 1997 PLANNER!

AUTO INDIA

JANUARY 1997

Rs 20

INDIA'S LARGEST SELLING AUTOMOBILE MAGAZINE



ANAMIT SEN brings you an exclusive scoop on India's first electric car, the REVA that shows much promise of being a cute little 'green' runabout.

REVA Revolution

Pollution. That's the buzzword nowadays. Air pollution, sound pollution, water pollution, plastic pollution, CFC pollution — name it and it's polluting something. But what governments the world over are most concerned about, today, is air pollution.

It has been argued that in urban areas, automobile exhaust emissions are the chief cause of air pollution. And as the number of cars increases steadily, so does the pollution. Thus, legislation has been brought in to curb exhaust emissions. California, USA, for example, has the most stringent regulations anywhere in the world because the dense automobile population there is the cause of some of the most polluted cities in the world. The regulations are based on a theory called Trickle-down Emission Control, the general idea being to introduce new low-emission cars which will gradually increase in number over time. Over the same time, people will start scrapping their old cars. Thus, pollution levels will eventually decline as there will only be newer, low-emission cars on the roads. In reality, though, trickle-down emission control has not worked very well and never will — people are sentimental, thrifty and sometimes just plain unable to afford new cars. Therefore, as long as older and/or poorly-maintained cars remain on the roads, the problem of pollution will not go away.

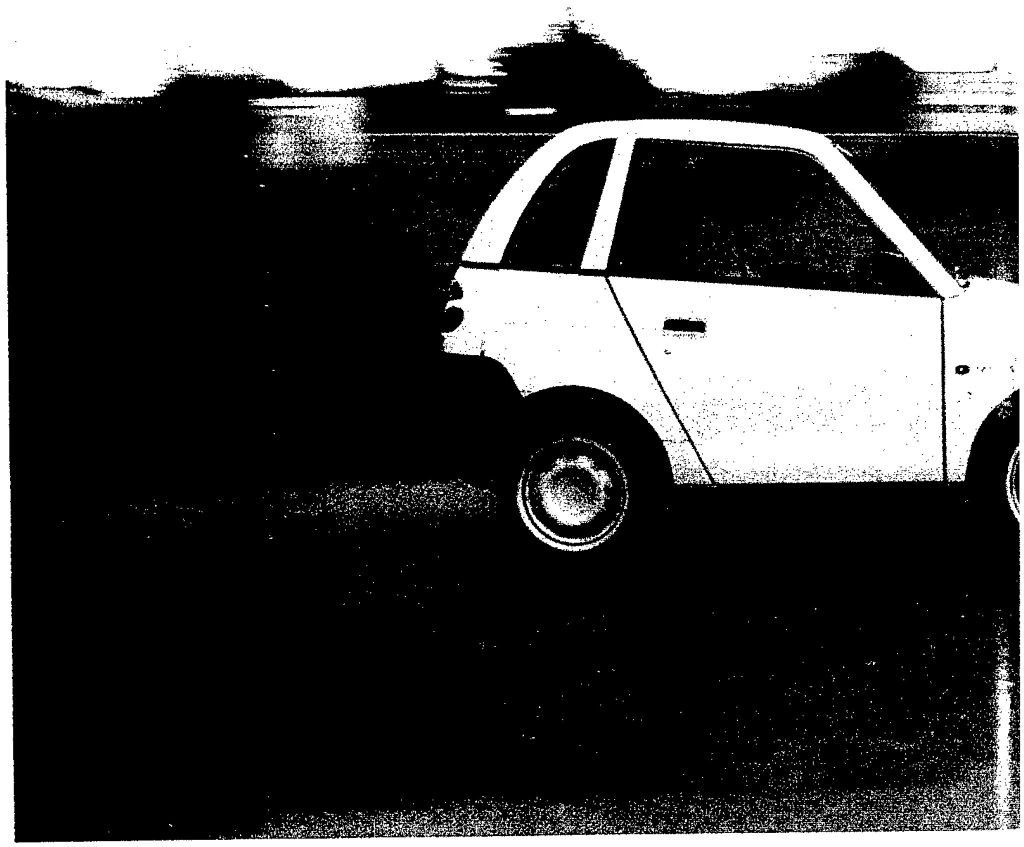
In fact, years after emission regulations were first implemented, the air in California remains polluted. According to one report, the pollution in the air in the Los Angeles area exceeded the maximum levels allowed on 124 and 118 days in 1993 and 1994 respectively. Closer to home, in New Delhi, pollution levels at peak traffic hours are so high the supreme court has deemed it necessary to direct the Gas Authority of India to look at the possibility of propane as an alternative fuel.

As always, California has decided to take a tough stand against air pollution and regulations now specify that by 2003 AD, ten per cent of all cars sold must have zero emissions. This can only be achieved by electric, solar and hydrogen propulsion. Consequently, research is on in labs around the world to make alternative energy sources viable. GM, which is working on several different sources of energy, including solar, has been working on the Impact project which, till date, has produced an electric vehicle but at a very high cost. The company only recently put its electric car into serious production.

Meanwhile, others have converted everyday cars to electric motor drive. Peugeot has an *electrique* version of the 106 small car, while Citroen has done the same to its AX model. Oxford, the university town in England, has even applied the EV (electric vehicle) concept to the town bus, and in France, cities are completely backing EV projects — city municipalities have made parking free for EVs, making it easier to use them for in-town running. The ideal situation would be for people to drive to one of several EV stands around a city, hire an EV and go into town. After completing one's work, one simply returns to the stand and drives off in one's own car!

Yet, the EV is not completely problem-free. Most existing EVs have been built around existing petrol/diesel car designs. The result is that the car tends to weigh more than the fossil fuel equivalent, thanks to its hefty lead-acid batteries. This is a vicious circle — more weight means more power is required. More power means more batteries are required and more batteries mean more weight, and also more time to recharge. Current lead-acid battery technology is incapable of providing a really good working range. Currently, more range means more power required. More power required means more batteries. More batteries means... You get the picture.

At a seminar on EVs however, it was pointed out that the only way to

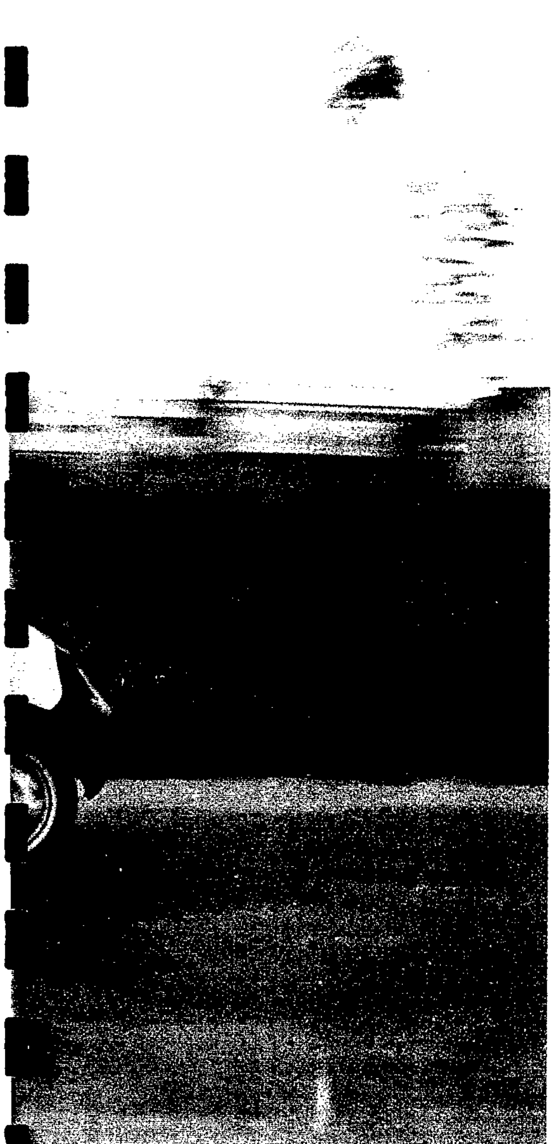


introduce zero-emission vehicles was to go in for lead-acid batteries in the short term, whilst continuing research on nickel-cadmium batteries to bring the price down. As things stand, though, we are stuck with the lead-acid battery though better production processes, design improvements and optimisation through the use of newer materials have resulted in more reliable and longer-life batteries.

At Oxford, they found a way around the weight, cost and charging time problems. A compromise actually: the number of batteries on board the City Circuit Electric Bus is limited to 'route specific' requirements. After a full overnight charge, several partial recharges *en route*, plus regenerative braking, the bus winds safely on its rounds through the city.

But the batteries require space. While a bus may have a lot of space available, the only available space in a car-turned-EV is the boot. Therefore you lose out on luggage space. And though it may be possible to use nickel-cadmium batteries, current nickel-cadmium technology comes with an exorbitant price tag — 60,000 French francs for one car. Don't even bother to convert that into rupees! And when you realise that the *electrique* car costs about one-and-a-half times (without batteries) the price of the petrol version, you begin to wonder what the point of it all is.

Government support is crucial to



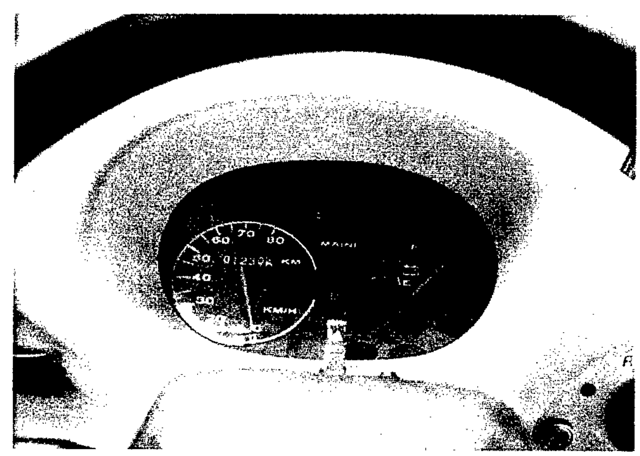
the promotion of any new concept. Subsidies, exemption from excise duty, sales tax concessions all go a long way in getting a venture off the ground. Nowhere is this more true than for something as radical as an electric vehicle. Legislation could force the use of more EVs in everyday work specially at airports, for school buses, at electricity boards and as public transportation.

The solution could well lie in a rethink on the EV. Instead of converting existing cars, a grounds-up design for an EV would work out much cheaper. In such a case, the designer knows exactly what he or she wants to do. This is the thinking of many designers today. Like at GM, whose Impact costs over 30,000 dollars. And Maini Amerigon in India whose REVA costs a fraction of the Impact.

THE MAINI STORY

The Maini Group has come a long way since the day it started off with just ten men. The group's annual turnover is well over the Rs 50 crore mark and there's no sign of the growth abating. The group comprises Bangalore Commercial Corporation, Maini Industrial Consultants, Maini Precision Products, Maini Materials Movement and Maini Granites.

It started in 1973 with Sudarshan Kumar Maini giving up his job at MICO to strike out on his own; today Maini Precision Products is a major supplier of components like diesel fuel filters, hand primers and filter inserts to MICO. The major activity of the company is to manufacture and. export high-precision auto components to Europe and America; its customers include GM, Bosch, Lucas and Blue Giant.



Maini Materials Movement was born out of a need to transport men and materials in a non-polluting manner at the Maini Precision Products plant. Indeed, the contrast between materials movement methods in India and those in developed countries was glaringly obvious. The company was not afraid to look towards local talent and designer Rajesh Mirajker was roped in to design an EV for VIP use in factories.

Now, the Maini Group is all set to enter the domestic market in a big way with its latest venture — the Maini Amerigon Car Company which will mass-produce EVs in India. Amerigon Incorporated is based in California under the presidentship of Dr Lon E Bell who is the recipient of over 30 patents and has developed sensitive seatbelt retractors, glowplug controllers, airbag crash sensors and pressure and vacuum sensors for diesel engines. Amerigon has also designed and built the first EV with an aluminium spaceframe in the US and manages EV programmes for the US government and California state agencies.

According to the Maini Group chairman, Dr Bell's son and Chetan Maini worked together on the Sunraycer. And it was while visiting Chetan in 1994 that he met Dr Bell. The idea of a city EV for India, the REVA, was born there, and in the December of '94 an MOU was signed. Amerigon and Maini are joint venture partners in a new company and the FIPB has recently cleared it for a foreign equity participation of 67 per cent. While Sudarshan Maini will be the chairman, Amerigon and Maini will have two members each on

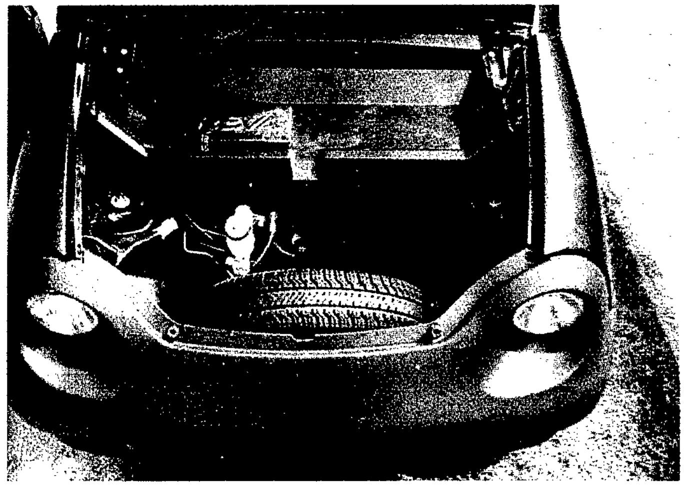
the board, while O P Khanna is the managing director.

The factory will be put up at Malur, 50km from Bangalore on the Chennai/Kolar road. The Karnataka government has put up an industrial estate there similar to Peenya and Bommasandra. Fifteen acres of land are available to Maini Amerigon, and the plan is to invest 30 crores in a 100,000-square-foot factory. Funding will be done by Maini, Amerigon and venture capital. The banks will be approached only for working capital.

Considering the cost of the project and the selling price of Rs 1.6 lakh for the car, one has to wonder what sort of production figures will be required to break even. Sudarshan Maini is confident: "Six thousand cars is the initial capacity of the plant. We plan to achieve full capacity within the first two years of starting the plant. As per our project, we will break even at 4,500 cars."

O P Khanna adds: "Initially we are targetting the city of Bangalore only. We hope to enter into the market with about 75 per cent indigenous content. The exact figure may vary a bit, as negotiations on the price are on with suppliers."

An important factor affecting the decision of buyers is the cost/kilometre which, of course, will vary from state to state. As the REVA consumes 10.5 units over 60km (a conservative estimate), the cost per kilometre, based on (heavily subsidised) Rs 2.50 per unit, works out to 43 paise per kilometre. With an 80km range, the cost/kilometre falls to just 33 paise. For a car that returns figures of 15kpl, with petrol at Rs 25 per litre and diesel at nine rupees, the cost per kilometre in Bangalore works out to Rs 1.66 and 60 paise per kilometre respectively. The REVA is obviously much cheaper than either a petrol or diesel equivalent!

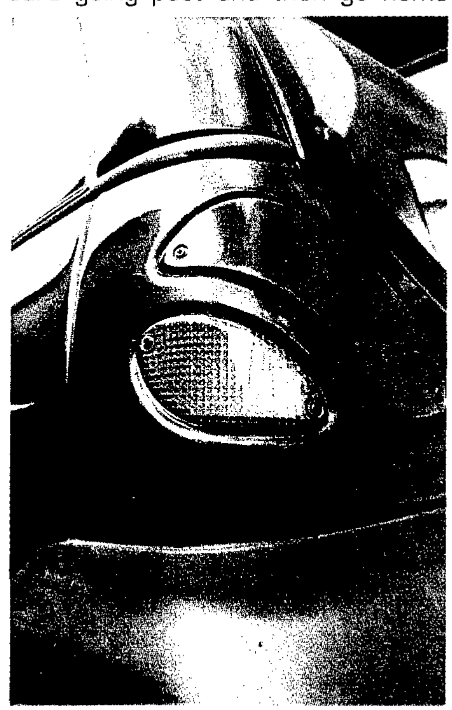


O P Khanna feels this will be a major deciding factor, along with the price of the EV for the targetted market — students, professionals, housewives out shopping, and mothers transporting children to and from school. Negotiations are on with the Karnataka State Electricity Board, the Bangalore Development Authority and other urban development agencies for subsidised electricity, special plug-points in high-rises, free parking and other concessions.

With the REVA launch planned for late this year, Maini Amerigon has a year in hand to get the negotiations and all the infrastructural support issues sorted out. Only then will the EV be a viable alternative.

THE REVA

I love listening to car exhausts. I'm the sort of guy who can sit by a race track the whole day listening to the cars going past and then go home



satisfied that I've done a good day's work. I also love to drive cars. Sometimes I get to drive them before anybody else: perks of the job, you see. I've marvelled at a turbodiesel and sworn at a particular one-litre car. I've hit tram tracks at 80kph on rally-proven suspensions and lurched drunkenly whilst changing lanes at speed. But I was totally bereft of feelings when I was told to drive Maini Amerigon's REVA. You see, the REVA is an electric vehicle or EV. Electric — that means no exhaust note. How do you get turned on by a car that has no exhaust note?

To get an idea of EVs, I went across to the Maini Materials Movement plant and drove an electric 15-ton tow tractor — the sort used in airports the world over. Then it was onto the REVA.

The first thing I noticed was the car's radical two-box styling. But something was wrong somewhere, it didn't quite feel right. Maybe it was the excess space in the door shut-lines. Maybe it was the 'home-made" look of the design, or the cheap indicator lights, sourced, perhaps, from a manufacturer of cheap toys. So I decided to call in an expert on automotive design. More on this later.

Back to the car. Open the bonnet and a space is revealed. Quite a large space. Even after the spare tyre and the brake fluid reservoir, there is bags of room left over. And above the firewall there's a shelf which could easily be turned into additional storage space.

I decide to check out the interior. Surprisingly, getting in through either of the two doors of the REVA is refreshingly simple compared to the 'side-twist-and-flop' one has to perform to get into modern cars nowadays. Apparently, the entrance has been designed with sari-clad ladies in mind. Good on yer, mates!

Once in, the bench-type seat, which covers the eight six-volt batteries, is firm and supportive. I cast my eye around the cabin — there is a rear seat, but just about. It is much better folded back, to make use of the resulting space for luggage. The seatbelts mounted on the B-pillars ensure that this little car conforms to the Motor Vehicles Act. Although there is a cabin light, it is not a courtesy light. For a short person like myself there is ample headroom though the narrow track means the passenger has to slant his legs across the cramped footwell to be comfortable. Sliding glass windows with a simple catch do away with greasy, mucky window glass that always seem to give trouble when it rains. Very minimalist here.

The moulded plastic facia is rather futuristic — it incorporates an oval instrument binnacle housing an oval speedometer, a battery-charge indicator, and oval indicator lights. There is a double-throw rotary switch for selecting drive on the facia, to the right of the steering wheel — reverse, neutral and forward. Just below the facia is the parking brake.

Seated in the cabin, with the windows shut, you begin to feel uncomfortable after a while. The car lacks an air-conditioner. But Maini Amerigon has a trick up its sleeve — production models will come with climate control seats (an Amerigon patent) where the seat temperature itself can be varied.

The Trojan batteries, under me, are connected in series. There is a single-point automatic watering system and the watering is done once a week. The batteries are enclosed in a moulded polypropylene box. The charger handles voltages between 170 to 260 volts and can charge upto 80 per cent from a fully-discharged condition in three hours. Full charging is done in eight hours, the extra five hours is for equalising the batteries. A DC-DC converter is used to step the voltage down from 48 volts to 12 volts, to operate the lights, wipers and accessories such as a radio.

The high point of the REVA is the EMS — the energy management system is an Amerigon component which continuously monitors the batteries, records power consumption and uses algorithms to extend range and battery life. A microprocessor-based system, it is completely self-diagnostic and has an interface which, when connected to a laptop, provides information to the service technician. It also controls a battery-charge indicator on the instrument panel and just below the facia is a digital display of a smart gauge — the EMS display. In production models, though, the EMS display may be relocated elsewhere.

By now curiosity has got the better of me and I had to drive the car. The procedure is very simple. Turn the key, then turn the rotary switch,

CHETAN MAINI


Chetan Maini.

Chetan Maini is the project manager (AEV) at Amerigon Incorporated. He was the key design team leader and crew member of the University of Michigan's solar-powered car which came first in the GM Sunrayce in the US and third at the World Solar Challenge in Australia. Later, he was the powertrain team leader for the Stanford hybrid electric car project where he worked on the development of a high-efficiency AC induction drivetrain. At present he is the man behind the design development of prototype fabrication of an EV for the Indian market.

AUTO INDIA: What is the future of the internal combustion engine, as we know it, and what are the 'clean' alternatives to fossil fuels?

CHETAN MAINI: The future of the IC engine is still very bright as we have petrol reserves for the next 50 years. The cleaner alternatives to fossil fuels include fuel cells, hydrogen, solar batteries and flywheels.

AI: What was learnt from the GM Sunraycer project of which you were a part at the University of Michigan?

CM: The Sunraycer project helped us optimise the efficiency of the vehicles and also better understand the parameters that affect a vehicle's performance.

AI: Has anything from the project been incorporated in the REVA?

CM: The simulation along with the system design approach was directly transferable from the Sunraycer project.

AI: Apart from basic EV specifications, what design elements of the REVA are particularly relevant to India?

CM: The small turning radius allows easy manoeuvrability and parking. Then too the higher seating allows easy entry/egress especially for sari-clad women. The ABS panels prevent dents in the event of low-speed collisions, and, lastly, there are the heated and cabled seats.

AI: Considering the need for internal space, and considering the space available under the bonnet, why was a rear-wheel-drive configuration selected?

CM: Three reasons: Lower costs as it avoids the use of CV and universal joints; it packages better; and it gives more crush space in the event of frontal collisions, thereby increasing safety.

which turns with an awful *clack* to select forward drive. Then slowly press the accelerator. As the series motor starts up, there is a loud high-pitched hum from the rear which dies down as you start moving. The very high torque is immediately available, so, should you choose to jam your foot down, the REVA will shoot forward at a very high rate of acceleration. Want to reverse? Two awful *clacks* this time as you move the switch through neutral to reverse drive. Careful as you step on the pedal, for the same acceleration applies in reverse drive too — one must keep a foot on the brake and use it like a clutch while reversing. I was assured later that the computer could change the reversing characteristics.

Driving over speed-breakers requires a certain knack, I discovered. Not too fast an approach or the live solid axle will cause you to bounce over it. Too slow and the car stops dead. Funnily enough, I kept thinking of changing down to second gear as I approached them.

The DC motor from GE is mounted directly onto the live rear axle and is coupled through a 7:1 ratio differential. Top speed is 65kph on fully-charged batteries, and with the foot down, the REVA pulls strongly up inclines. The chopper-controlled motor has a built-in regenerative system for braking. For higher braking demands, the hydraulic system is engaged and the chopper circuit, from Curtis, is protected from overheating and short-circuits. In fact, the four-wheel dual-circuit hydraulic system operating the drum brakes is the only major component which is still conventional.

The steering wheel is comfortable to hold, while the rack-and-pinion steering is direct and has a short turning circle diameter of 6.6 metres. The REVA is easily controllable with one hand at low speeds. The front suspension is independent and comprises MacPherson struts with a lower control arm; the rear suspension is somewhat primitive — leaf springs with telescopic dampers. Talks are on with leaf spring manufacturers regarding the implementation of a single parabolic leaf spring.

Charging around the shopfloor

Photographs by Anamit Sen

(not my idea of a test track) and the dirt road leading out of the factory, I found myself quite liking the car's quick responses. But try to turn the REVA with your foot on the accelerator and it understeers massively despite the low-profile 145/60 R14 Michelin tubeless radials.

The REVA weighs 672kg, of which the Trojans account for 240kg. The chassis is composed of MIG-welded rectangular and tubular steel sections. All body and interior mounting points are directly welded onto the chassis and before final assembly the entire frame is zinc-coated. The exterior body is comprised of thermoformed high-impact ABS panels — fenders, doors, tail-lights — while the bonnet and roof are of resin transfer processed fibreglass/resin compound. Charging is done via a standard Indian 15A wall plug.

What draws my interest is that there is no oil to be changed, no body rust to be dealt with, no starter motor to get jammed. Driving the REVA is like driving a car with automatic transmission. My only worry is the differential which seems to jut out under the live rear axle. It reminds me of the Sipani Dolphin.

And, remembering Sipani, Maini Amerigon is determined to make a success of the venture. A factory is coming up in Malur a little outside Bangalore and since 75 per cent of the REVA's components have been sourced from India, there is a good chance that the car will be launched with an even higher percentage of indigenisation. The company is negotiating with several government agencies to make the car easily acceptable to the general public. At a targetted price of Rs 1.60 lakh, it will be the cheapest car around. And, at a conservative 40kpl, it should also be one of the cheapest to run. The launch period is late-1997 but, as they say, there is many a slip between the cup and the lip. Hopefully this is one venture that will defy the proverb and take off. It deserves to. ◆

REBONI SAHA, an industrial and automotive designer based in Goa, writes of her first impressions of the little electric vehicle.

Electrics are not new. Time and again we've seen little *dabbas* bolted onto a motor and battery. All very noble. But in their hurry they forgot that nobody, but nobody likes to be seen in excuses for vehicles. And that's where the little REVA has me ecstatic. Unlike so many of our myopic Indian companies, Maini Amerigon has invested in design. May the company be rewarded handsomely for its foresight. And now, having jumped onto the design bandwagon, we shall critique.

Apart from commendable fit-and-finish, many accepted details have been used from the present automotive design idiom. Merged well, mind you, not just slapped on. The Fiat Ritmo/Strada-style car bra, those slab sides with gentle negative curves — a favourite with the new jellybeans. The Mazda Xedos, the Ford Taurus and a host of Hyundais have got people to appreciate this as a new aesthetic. So, where else could it be justified more than on an already slab-sided electric car?

Looking at the rear though gets me uncomfortable. Those oh-so-different rear lamps curving nicely around the rear — they have character, yet they sit too large and too close. Such backsides suit Ferrari-esque wheelbases — wide and slim. The profile? Well, imagine this: Enter neighbour's kid Raju. With pencil in hand he sees the side view and draws an angled windscreen levelling off into a straight roofline. Past the B-pillar as he decides to take the plunge, images of jellybeans flash through his mind. "Got to put a curve there," he thinks and arcs down to join the waistline. This was not a smart move. The meeting as we see is an unhappy one. It turns out to be a caricature sitting atop a nice body, exaggerated by a somewhat ambitious forward rake and a disproportionate rear overhang. What justified a cab-rear in these days of cab-forward design? If I had a REVA I would save my ego and lop off the top — a cabrio would be neat.

The interiors are well done, the trimmings leaving a good impression at first glance. While they obviously indicate extreme economy in the use of materials, the facia is another thing — far too shiny, cheap and plasticky. Some matt effects or texture would definitely go a long way.

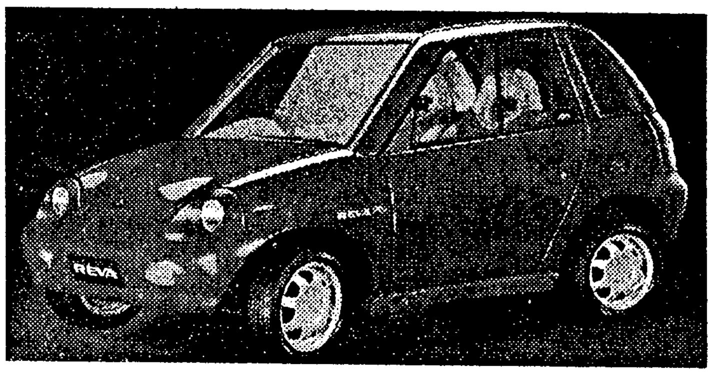
Despite my nit-picking, which is my job as a critic, this car evokes a positive response. It is partially helped by its unavoidably cute dimensions. And that's how it will be, until something more proportionate comes along.

Fact is, though it has surpassed expectations in its effort at a more refined appeal, it still has that 'Designed in India' look about it. Q E D.

THE FINANCIAL EXPRESS
THURSDAY, DECEMBER 19, 1996

Reva to storm Indian roads next year

FE NEWS SERVICE
BANGALORE, DEC 18



THE Bangalore-based Maini Group in association with the US-based Amerigon will launch 'Reva', India's first electric city car by the end of next year. The bookings for the car which will be priced around Rs 1.6 lakh will commence in February next year and the first car will roll out in April 1997.

Reva will be one of the first mass-produced electric vehicles (EV) in the world. The technology for the car is the same as the one used to design the latest Boeing 777 and the Saturn car of General Motors. It has been designed and built specifically keeping in mind the socio-economic and social infrastructural conditions of India. It is light, simple, rugged, reliable and safe to use. It can accommodate two adults and two children, easy to drive and park. The most important feature of the car is that it is non-polluting and quiet. The running cost of the car is less than that of a scooter and is charged by eight electric batteries. The batteries can be charged from a normal 15 ampere plug point. The total time taken to charge the batteries is five hours and the cost works out to around Rs 22 for full charge.

The car is cost-effective as it has very few moving parts and hence nil maintenance. It has no gear box, engine, clutch, starter motor, radiator and exhausts. It has an in-built energy management system with self-diagnostic capabilities. Built with tubular steel the car can withstand high loads.

Unveiling the car in Bangalore today, Joshua Newman, CEO, Advanced Technology Group, a division of Amerigon, said that the car is ideally suited for India. "Electric technology is not suited for the West as the cars have to have very high speeds. The Reva which has a top speed of 50-60 kilometers per hour is ideal for the Indian roads."

The two companies have set up a joint venture called Maini Amerigon Car Company Pvt Ltd for the project. The plant for the project will come up at Malur in Karnataka at a project cost of Rs 30 crore.

In the first year of operations the company plans to source 50 per cent of the components from domestic market and by the third year to 70 per cent.

Giving details of the funding pattern, Sudarshan Maini, chairman, Maini Group, said the promoters would hold a stake of 35.5 per cent while Amerigon will hold 34.5 per cent. The remaining amount will be raised through the venture capital route. The company is already in talks with ASC Singapore, a leading venture capital fund. "The Singapore company has already agreed to pick up a 20 per cent stake in the venture. Negotiations are on for the remaining 10 per cent," he said.

The company plans to roll out 6,000 cars in the first year and expand it to 20,000 later. Maini revealed that the company has already firm export orders from Nepal, Sri Lanka, Mexico, Austria and Germany. It has already opened a letter of credit with Nepal for exports. The company expects to break even once its production touches 4,500.

The company is also in talks with the ministry for non-conventional energy resources for getting more sops by way of prices, said O P Khanna, managing director, Maini Amerigon Car Co.

Maini is a diversified group of companies with an annual turnover of Rs 50 crore engaged in the manufacture of high-precision automotive components and assemblies for original equipment customers both in India and abroad. Amerigon is a $ 10 million vehicle design, systems engineering and component supplier in the US.

Electric city car from Bangalore firm

From Our Special Correspondent

BANGALORE. Dec. 18.

The Bangalore-based Maini group. which manufactures precision components. material handling equipment. bio-detergents. granite tiles and abrasives. unveiled at a press conference in Bangalore today its latest product. Reva. a two-door hatch-back battery-powered car meant for city use.

Research has shown that most urban car owners in India use their vehicles primarily for in-city travel. The average distance covered per person in a day is 15 to 40 km and that the average speeds are 12-20 kmph during peak hours and 25-40 kmph during non-peak hours. Based on these use patterns the Reva has been designed from scratch by Amerigon. a California-based design house specialising in EV (electric vehicle) design. With a payload of 225 kg (two adults and two children). the car has a range of 80 km on full battery charge and a top speed of 65 kmph.

The car is powered by a pack of eight lead-acid batteries specifically meant for EV use in that they can withstand a high number of charge/discharge cycles (600) to give a long battery life. The battery is charged with a 12 amps. 2 kW charger that can be plugged into a standard 220 volt. 15 amps wall plug. The charging rate is 80 per cent in three hours and the balance 20 per cent in another two hours.

A chopper controller enables braking energy to be fed back into the battery. A low battery power level indicator warns the driver when 30 km of driving power is still left. The car is fitted with a microprocessor-based energy management system that ensures optimum use of battery energy.

The drive train consists of a DC motor (6 hp continuous with 17 hp peak) coupled to a 7:1 single reduction gear which drives the rear wheels. The driver has to only operate the accelerator and brake.

Keeping the crowded Indian city road conditions in mind. the body panels of the car are vacuum formed from light-weight high impact-resistant ABS plastics to withstand denting due to bumps from other vehicles. The chassis is of steel tubes while the front and rear bumpers are of strong high density polyethylene.

The electric city car to be manufactured by Maini-Amerigon Car Company Pvt. Ltd.

According to Mr. Chetan Maini. the power consumption of the Reva will be around 9 kWh per full charge. which enables 80 km of travel. The replacement cost of the battery pack will come to around Rs. 15.000. The car will be priced at around Rs. 1.60 lakhs plus taxes. All told. driving in the Reva will cost about half that in Maruti 800 with the added bonus of virtually no parts to be regularly replaced due to wear and tear (barring the braking and suspension components). Add the fact that an EV entails pollution-free running and we have in the Reva an ideal vehicle for Indian cities.

Mr. Sudershan Maini. Chairman of the group. claims that already purchase enquiries are pouring in from the neighbouring countries as well as some European ones like Austria and Germany. The group plans to spend the next one year propagating the EV concept in Bangalore with a fleet of 60 cars and then take up manufacture by October 1997. under a new company called Maini-Amerigon Car Company Pvt. Ltd.

The manufacturing facility at Malur near Bangalore will involve an investment of Rs. 30 crores for a capacity of 20.000 cars per annum. Exports will commence from the second year. Initially the indigenisation level will be 50 per cent which will rise to 70 per cent by the end of the third year. The projected market size is 40.000 cars in 1998 rising to one lakh cars by the year 2000.

Maini Group: Riding High on Reva

Zero, is the mother of all beginnings. Yet, to the discerning, it is pregnant with possibility. So it was with the Maini Group too. In 1973 MICO, the Bosch subsidiary, had a need. S K Maini, who was a MICO employee had the solution for this. With just ten workers he began by supplying MICO a small but vital component. Today the venture is a multi-million rupee, multi-division group.

The group has grown steadily in many new directions. Today high precision components are as comfortably part of the group's portfolio as are biodegradable detergents. Auto assemblies rub shoulders with golf clubs, granite tiles with electric vehicles and stackers.

Sudarshan Maini, Chairman, Maini Group

Maini offers zero defect products. Quality is the most important thing for the group. The group's motto is 'Karma Parma Dharma" which means work is worship. Apart from the zero defect product the company is signified by zero time delays, zero compromises, zero pre-conceptions, zero excuses and zero inefficiencies. Quality and reliability are the cornerstones of all the efforts at Maini.

The company has made significant strides in its ventures by bagging big international clients like BOSCH, General Motors, Lucas etc. This was possible by identification of a genuine niche market,a complete and flawless integration of skilled human resources and the most appropriate technology.

The chairman of the group is Sudarshan Maini a technocrat of many years standing. A mechanical engineer by qualification he has several years of professional experience abroad.

The various operations of the group are precision components, granite, international trading and in-plant material handling equipment.

The pride of the group will undoubtedly be the 'Reva', India's first electric city car. The Maini group has collaborated with the US-based Amerigon for this venture.

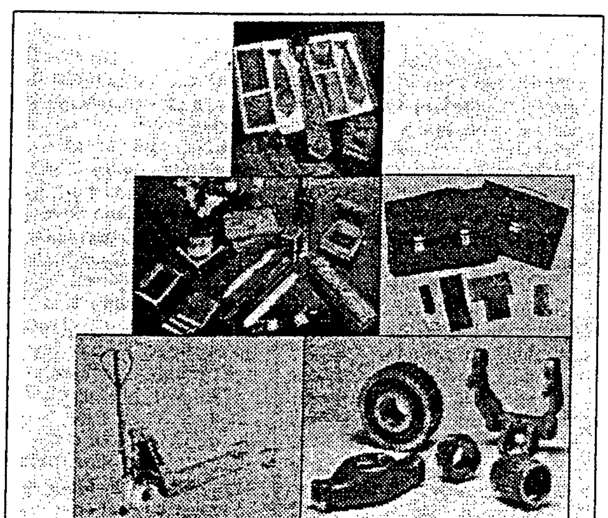
"India 2010 will act as a launch pad to project Reva car to the public," said Sudarshan Maini. The car is being targeted at all segments be it the IAS officials, top executives, CEOs or the young generation. It is the right choice for all, says Maini.

The car which is expected to hit the Indian roads in December 1997 will be answer to a smoke free world. No noise, no smoke, no parts, easy to use and safe to handle, that is Reva the electric city car.

Bookings for the car which will be priced around Rs 1.6 lakh will commence in February next year and the first car will roll out in April 1997.

Reva will be one of the first mass-produced electric vehicles (EV) in the world. The technolgy for the car is the same as the one used to design the latest Boeing 777 and the Saturn car of General Motors.

It has been designed and built specifically keeping in mind the socio-economic and social infrastructural conditions of India. It is light, simple, rugged, reliable and safe to use. It can accommodate two adults and two children, easy to drive and park. The most important feature of the car is that it is non-polluting and quiet.



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The car is cost-effective as it has very few moving parts and hence nil maintenance. It has no gear box, engine, clutch, starter motor, radiator and exhausts. It has an in-built energy management system with self-diagnostic capabilities. Built with tubular steel the car can withstand high loads.

The car has a payload of 225 kg and a range of 80 km. The top speed is 65 kmph and curb weight 672 kg. It has a wheel base of 1,659 mm and a track of 2,282 mm. The length of the car is 2,638 mm and width is 1,324 mm. Reva has a height of 1,510 mm and ground clearance of 152 mm. The turning radius is 3,350 mm and maximum gradability is 20 per cent.

Though the electric vehicle technology was developed in the West it has not found much favour there. This primarily because of the fact that in the West the cars run at very high speeds and fuel is cheap.

Cars which run on electric technology are unable to attain the top speeds abroad. In india, however with fuel prices high electric technology is the answer to all problems. for India. The Reva which has a top speed of 50-60 kilometers per hour is thus ideal for the Indian roads.

The two companies have set up a joint venture called Maini Amerigon Car Company Pvt Ltd for the project. The plant for the project will come up at Malur in Karnataka at a project cost of Rs 30 crore. In the first year of operations the company plans to source 50 per cent of the components from domestic market and by the third year to 70 per cent.

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Maini is a diversified group of companies with an annual turnover of Rs 50 crore engaged in the manufacture of high-precision automotive components and assemblies for original equipment customers both in India and abroad.

The group is one of the few that takes care of its employees. The chairman personally takes care to see that all their needs are taken card of like medical, schooling, marriages etc.

Revving up for REVA

Bangalore's own electric car is designed for the future, when vehicles will have to be smaller and more eco-friendly.

Photographs by S. ESWAR

• The small wonder geared up for the big time

Some of the latest technology incorporated in the car include an intelligent fuel gauge and battery system which is part of the very latest Amerigon-developed Energy Management System (EMS). And the car weighs just about 672 kg, all distributed at the bottom of the car which gives it a very low specific gravity, reducing any chances of it toppling over.

The company's Chairman, S.K. Maini, hopes to manufacture 6,000 cars every year initially. Hopefully, once production reaches 20,000 cars in the second year, it might be easier not only on the pocket but also the wait for a car may be reduced.

Though the company's projections say that the market for such an electric car will be around 40,000 initially, the car's light weight, ruggedness, ease in handling and low running cost may yet see a surge in demand. Anyway, the company says that the output will rise to 2 lakh by the year 2000.

Some of the car's features are the Climate Controlled Seat (CCS) technology whereby the seat gets cooled, and the regenerative braking technology which converts braking power and diverts it to acceleration. The company is bringing in the advanced "running chassis" and "space- frame" technology. The whole thing would be controlled by the EMS, which includes an intelligent fuel gauge and battery management system.

THE ECONOMIC TIMES
BANGALORE THURSDAY 19 DECEMBER 19

HOP IN, THERE'S ROOM FOR MORE: The electric car, Reva, is adequate to meet the needs of India's city dwellers, says the company

Reva to hit Indian roads in Dec 1997

Our Bangalore Bureau

BANGALORE 18 DECEMBER

INDIA's first electric car, Reva, will be available for commercial sale from December 1997. This was announced by the Bangalore-based, Rs 50-crore Maini group today, at the official launch function of the car. The car is expected to be priced at around Rs 1.65 lakh ex-factory.

Reva will also become the smallest car available in the country, said company sources. The company plans to open bookings for the car from February 1997. Mr S K Maini, chairman, Maini group of companies, said: "Reva is adequate to meet the demands of India's city dweller."

Reva is being produced by the Maini group in a joint venture with the $10 million Amerigon of US through Maini Amerigon Car Co Ltd (MAC). According to Mr Joshua Newman, president and CEO, Advanced Technology Group, Amerigon, the Maini group will hold around 45 per cent stake in the project while Amerigon will be a 35 per cent joint venture partner. The balance will be held by financial investors.

The project is expected to cost Rs 30 crore. MAC initially plans to produce around 6,000 cars annually which will be expanded to 20,000 cars annually on completion of one year of operations.

Mr Joshua Newman said there will be no exports in the first year of operations. In the second year, around 15 per cent will be exported and the exports will increase to 50 per cent from the third year onwards.

According to MAC, Reva will be one of the first mass-produced electric vehicles in the world. The company's press release said that Reva was designed and built specifically keeping in mind the Indian socio-economic and social infrastructural conditions. The car has a top speed of 65 kmph and a curb weight of 672 kg. It is expected to run 80 km per battery charge of around 5 hours.

The special features of the car include energy management system (EMS) and climate control seat system (CCS). EMS helps in intelligent fuel gauge and battery management. Mr O P Khanna, managing director, MAC, said EMS will tell how efficiently the parts like motor, controller and the battery have performed. Both EMS and CCS are patented in the US, according to Mr Joshua Newman.

DECCAN HERALD, THURSDAY, DECEMBER 19, 1996

First ever Indian electric car soon

By Our Staff Reporter

BANGALORE, Dec 18

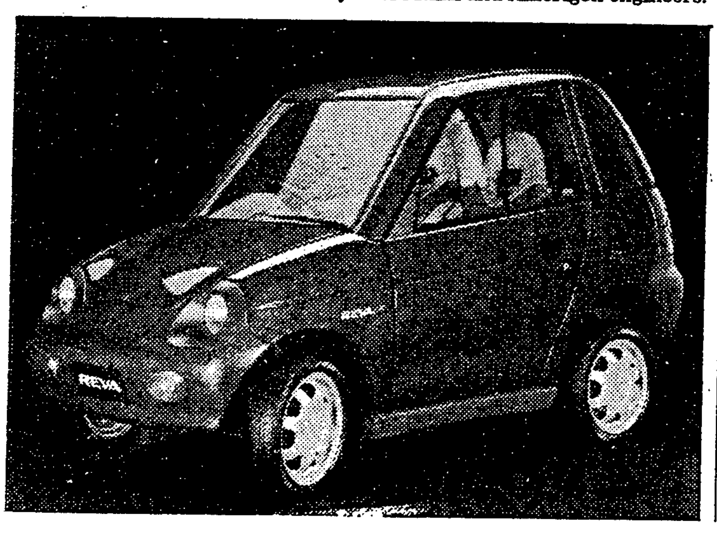
The Bangalore-based Maini group in collaboration with Amerigon of USA will soon introduce the first ever electric car into the country.

Reva, the car so named has been designed at Amerigon facilites in the US and will accommodate two adults and two children. Incidentally, it is the first ever mass-produced EV in the world. Designed and built specifically keeping in view the Indian needs, the car is light, simaple, rugged, reliable and safe, claims Maini group chairman Mr S K Maini.

Addressing a press conference here today, he said the car with a payload of 225 kg can travel upto 80 kms with a top speed of 65 kmph. Priced at Rs.1.65 lakh excluding taxes, the car has undergone high levels of reliability achieved by adopting an on-going process of FEMA (failure mode and effect analysis), undergone strenuous reliability and homologation tests conducted by ARAI, Pune and subjected to stringent road-worthiness tests in the US, he said. Besides, it has been equipped with latest Amerigon developed energy management system.

The car built out of light-weight impact-resisting ABS material is equipped with an array of 8 lead-acid batteries which can be re-charged at domestic households at normal 220V, 12A, 2KW with a standard Indian 15A wall plug. The batteries to charge for 80 per cent take 3 hours and the remaining 20 per cent can be charged in 5 hours time. It consumes 9 units of current per charge and effectively works out to Rs.22 or 40 paise per km as fuel cost to run for 80 km.

He said the first prototype, after meeting severe Californian test standarads, reached India in May. The company has manufactured components indigenously and shipped to US to be assembled at the Amerigon facilites by a team of Maini and Amerigon engineers.

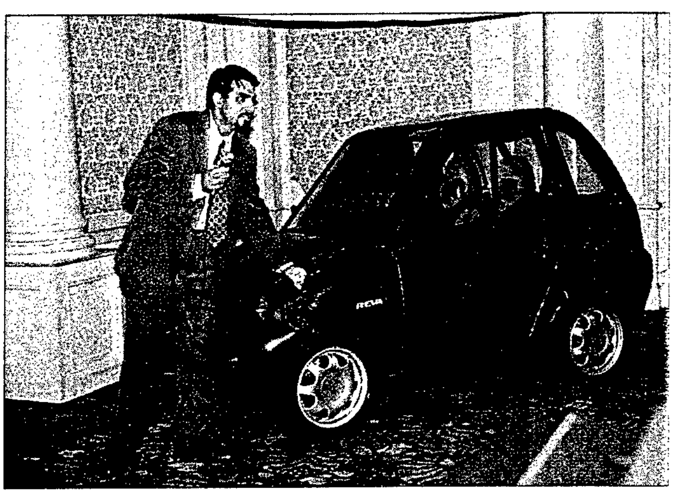


Something to rave about

The Bangalore-based Maini group has come up with Reva, India's first electric car as an alternative to petrol-driven vehicles

It is cute yet hardy, noiseless, environment friendly, inexpensive, practically maintenance free and most wonderfully — needs no fuel. And just recently, Miss World walked away with one. A turn of a dial makes it reverse or go forward. Two adults can sit inside comfortably with two very small children. This is the Rs1.6 lakh (plus taxes) Reva — India's first electric car launched ironically enough in the power-hungry city of Bangalore last month.

It is the result of a joint effort between the Rs50-crore Bangalore-based diverse manufacturing group, Maini and the $10 million Amerigon, America who are established leaders in EV (electronic vehicle) technology. Maini group chairman, S.K. Maini believes that Reva will be the city car for the future. Says the senior project manager at Amerigon, Chetan Maini (S.K. Maini's youngest son), "Electronic transmission makes this a very easy car to drive, the engine designed for in-city driving to prevent energy loss in the typical stop-and-go driving conditions." Reva has a top speed of 65 km/hour.


Sorab Mehta

Chetan Maini with the 'city car for the future'

Just plug in to a 15 amp point after every 80 kilometres, recharge batteries for a minimum of three hours to get 80 per cent charge or eight hours for a full charge, and you are ready to roll. Consuming nine units per charge, the approximate cost of running the vehicle in Bangalore will work out to 35 paise per kilometre. Eight lead acid batteries stored under the car cost Rs12,000-15,000 per set and have a life cycle of at least three-four years (500 to 600 full charge cycles).

An energy management system in the Reva controls all energy to and from the battery and continuously monitors the batteries and improves their life considerably. The car has a microprocessor-based system and is completely self-diagnostic. The Reva service technician only has to plug in his laptop to the car and it will provide all the necessary information. Another very interesting feature is the climate-controlled seat (for which Amerigon is registering a patent in America currently), where the seat gets cooled from the inside.

Though the car is very small and looks lightweight, explains Chetan Maini, in reality it is both very stable and strong. The placement of the batteries ensures a low centre of gravity which in turn guarantees high stability. "A steel space frame makes for a very safe occupancy cage in the event of collision and the high impact ABS vacuum formed panels (the same material as used in GM's Saturn) protects against dents."

The Maini group is well aware that people are going to take some time to get used to the concept of an EV. In fact, at the launch, a media person wanted to know whether people stood the danger of being electrocuted during the monsoon. The answer to this is an emphatic no given by Maini, since the motor and the charger are all well protected. The other very valid enquiry related to how would Reva owners in high rise buildings manage to plug in their car and whether there would be problems with the Electricity Board for drawing this power. The Mainis are talking with both the city electricity and development boards for subsidised rates and to allow builders to put in charge points in the basement/garages

Its exactly these kinds of concerns that is prompting the Maini group to go slow with their production plans. Says managing director O.P. Khanna of joint venture company Maini Amerigon Car Co (MAC), "We have intentionally decided to begin commercial production only in December 1997. Early on, cars will sell just on the curiosity factor but demand needs to be perpetuated. So we will release about 50 to 60 cars by midyear in Bangalore to check the people's response and whether any adjustments or improvements need to be made."

Initial production plans are for 6,000 cars per annum at a project cost of Rs30 crore. With the plant coming up at Malur, outside Bangalore, after completion of the first year, production will be expanded to 20,000 cars per annum. Export enquiries are already coming in and this will begin from the second year. The Mainis envisage a demand for about 100,000 cars by the year 2000. Excise duty on the ex-works price of EVs is only 10 per cent as opposed to 40 per cent for petrol/diesel vehicles, and negotiations are on to bring this down to zero. Reva is also exempt from road tax for the first five years.

Says Joshua Newman, managing director and CEO of the California-based Advanced Technology group, Amerigon, "Manufacture of EVs in America is constrained by the fact that the minimum feasible plant size is one of 200,000 units, and costs are very high for smaller numbers. For instance, GM's EV 1 costs over $35,000 which will find few takers. While California has been leading the way in the business till now, this is a historic opportunity for India to show the way instead."

■ MOHANA PRABHAKAR

Getting a charge out of India

Monrovia-based Amerigon signs agreement to help produce economic electric cars for that country

By Brett Sporich
STAFF WRITER

MONROVIA — Hoping to tap into the expanding incomes of India's emerging middle-class, Amerigon Inc. has joined forces with an India-based company to produce low-cost electric cars in Bangalore, India.

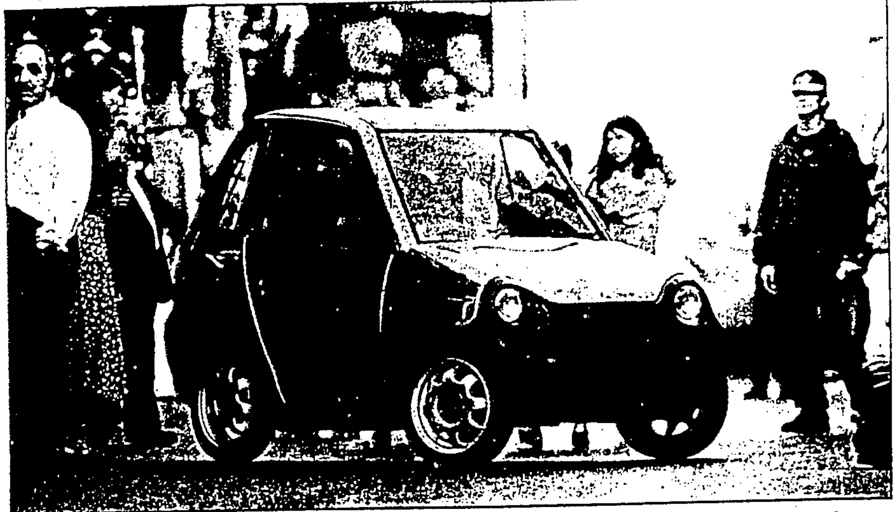
Monrovia-based Amerigon, which recently introduce an interactive navigation system that runs on a modified CD player, has signed a preliminary agreement with India-based Maini Group to form a joint venture.

Under the agreement, Amerigon will hold approximately 40 percent interest in the venture and provide production design, prototypes and manufacture the car's high-tech components.

The Maini Group, which manufactures electric fork lifts, pallet trucks and other related equipment, will hold another 40 percent interest in the venture, with the balance being held by ASC Capital PTE, Ltd., a Singapore-based investment group.

The REVA, as the vehicle is called, is expected to retail for less than $6,000 and will be assembled in India. Amerigon will manufacture about 25 percent of the car's parts, such as the electric motor, its patented energy management system, and the REVA's charging system. The energy management system directs the flow of electricity throughout the car to get the most out of battery power.

Because of low labor costs and lower standards and expectations for vehicles in India, the REVA can retail for a fraction of what electric cars sell for in the United States. By comparison, the EV1 produced by General Motors Corp. and Edison EV will sell for about $35,000 when it hits Saturn dealership showrooms later this year



THE REVA ELECTRIC CAR has a range of 65 miles and a top speed of 45 miles per hour, making it a possible alternative to India's motor scooters.

But the REVA doesn't meet the same range, speed or safety standards that the EV1 must meet. That's because the motor scooter is a major form of transportation in India, where there are very few freeway-like highways.

"The REVA is designed for the growing numbers of middle-class professionals in India, who typically ride motor scooters in city settings," said Lon Bell, chairman and CEO of Amerigon.

The short and stocky REVA has a range of 65 miles and a top speed of 45 mph. For an additional cost the REVA comes with Amerigon's patented climate control seats that both heat and cool passengers using a fraction of energy that an air conditioner uses.

Since the trend in deregulation and the limiting of government control of markets — such as cars — India's motor industry has grown rapidly, according to The Economist Intelligence Unit, a London-based research company.

And the most rapid sector of that growth is in what are called "mini cars," typically short and stocky vehicles that carry two passengers, like the REVA.

But that's where the similarities end. The REVA, unlike other mini cars made in India, runs on electricity, not gasoline. In a country where gas stations are not as plentiful as they are here in the United States, an electric-powered vehicle might be an advantage.

"There is a problem with frequent blackouts in India's metropolitan centers — but those occur during the day," Bell said. "Most vehicle charging will be done at night, when power is more available."

The REVA's charging system works with electric systems in 80 percent of India's urban dwellings, including apartments and houses, according to Amerigon's market studies.

Bell, a CalTech graduate, founded Amerigon in 1991. Since that time the public company has been in what Bell calls "a development stage," running in the red. But that appears to be changing as net losses continue to decline and profits from products begin to bolster the company's bottom line.

The company reported revenues for its first quarter ending March 31 had increased more than fourfold to $3.8 million from $897,000 a year ago.

For the same period a year ago, Amerigon's net loss narrowed to $370,000, or 9 cents a share, from $1.2 million, or 39 cents per share.

REVA

- **TYPE:** Electric powered, two-door passenger car
- **PAYLOAD:** Two adults, plus two children; (507 lbs.)
- **TOTAL WEIGHT:** 1,170 pounds; (aluminum frame)
- **WHEEL BASE:** 65 inches
- **LENGTH:** 8 feet, 6 inches
- **BATTERY CAPACITY:** 6.14 kw hours
- **CHARGE TIME:** 6-8 hours

Founded by Lon Bell, right, in 1991, Amerigon reported that revenues for its first quarter ending March 31 had increased more than fourfold to $3.8 million from $897,000 a year ago.

Staff photo by MICHAEL HAERING

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

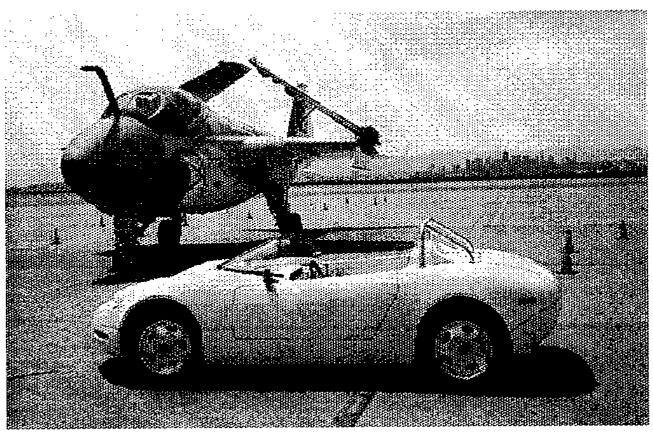
CALSTART PROJECT HATCHERY NORTH FINAL REPORT

CALSTART

Project Hatchery Alameda
Final Report

MDA 972-95-2-0011

DARPA



Submitted by:

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CALSTART
Project Hatchery Alameda
FINAL REPORT

1. **Introduction** The objective of this project was to establish a self-financing business incubator for advanced transportation technologies at NAS Alameda. Funding was used to partially defray the start-up costs of Project Hatchery Alameda, as the incubator is called. Specific activities funded included:
   1) Develop a business plan
   2) Identify potential sponsors to donate resources and equipment
   3) Market incubator and recruit start-up businesses
   4) Develop service provider network for incubator companies

2. **Accomplishments** All of the activities identified were accomplished within schedule with the funds provided and matching funds from CALSTART.

   2.1 Business Plan A business plan was completed prior to the end of FY96.It was revised during FY97 with two options and reduced to a work plan for PHA. An outline of the plan, the work plan and initial proposed operating budget are attached. (See also Sec. 6.1)

   2.2 Identify potential sponsors The following organizations were qualified, proposed to and became sponsors of PHA:
   1) U.S Navy: provided shop tools and machinery; furniture and appliances
   2) Pacific Gas & Electric Co.: provided direct funding and office equipment
   3) Hewlett-Packard: provided direct funding and office equipment
   4) Bronson, Bronson & McKinnon: provided direct funding and offered pro bono legal consultation as a service to PHA companies
   5) The Mills Family Fund: provided direct funding
   6) The San Francisco Foundation: provided direct funding
   7) Howard, Rice, Nemerovsky et al: pro bono legal services to CALSTART in the negotiation of the facility lease with U.S. Navy

   Proposals have been made to two more potential sponsors of PHA with the funding decisions not yet known.

   2.3 Market Incubator; Recruit Start-ups PHA has been marketed according to the elements of the business plan through presentations, extensive media coverage, and special events held at the former NAS and the facility itself. The number of companies grew from six at inception to a maximum of 19 during FY97. Four companies have transitioned out of the incubator: two into other facilities on base. There were 16 small businesses in residence at the end of this contract period. Funding from foundation grant sources has been budgeted for a sustainable outreach and PHA marketing program to be professionally designed for on -going implementation by permanent staff. Given the exiting space configuration of Hangar 20 and the advanced transportation technology start-up business requirements, 20-22 small companies are the maximum that could be simultaneously accommodated. This is a workable number for sustained staff support, also. An average of 15 formal presentations per quarter have been given by CALSTART about, or at, Project Hatchery Alameda and the offered program.

2.4 Service Provider Network The number and type of firms in the PHA service provider network has varied over the incubator's operational life.
The planned mix includes law and accountancy firms, management consultants and similar business advisors, and insurance brokerages willing to work with small and start-up businesses. Currently, there are three law firms, two accountants, two business consultants, and three insurance brokerages providing pro bono consultation and services or, offers to work at significantly advantageous discounts, to the CALSTART PHA companies. These relationships have paid off for at least three of the provider companies as they were subsequently engaged as a result of their involvement in our service network.

3. **Deviations to Plan** The stated objectives were achieved. Deviations to the originally proposed plan included expansion of tasks to include identification, validation and negotiation with Navy and Re-use Authority for a vehicle test track accessible from Hangar 20, to be used under CALSTART management for clean fuel vehicle R, D & D. Planning and execution of a trial Electric Vehicle Exposition for local and regional media and the general public was also completed. Results were positive: enough to warrant proceeding with a complete International EV Expo at Alameda next year, intended to be a revenue source for PHA operation as is the test track. This also fits into the other part of this funding package: NAS Cluster Planning. Additional detail will be provided in that final report.

3.1 While all contract objectives were achieved, some detail items in the business plan were not implemented. Most notably: staffing and the advisory board. A facility maintenance person was not contracted in FY97, primarily as a cost-saving measure. Formation of a representative advisory board, including interested sponsors, was initiated but not completed. This effort is to be continued as it is considered a valuable resource by PHA management.

4. **Projections** There are no events identified that will negatively affect the project goal of establishing an advanced transportation technology business incubator at the former Alameda NAS. This has been achieved. The alternatives that expanded project scope: test track and Annual Exposition, have already been identified. These will be pursued so long as they provide additional on-going sources of revenue.

5. **Financials** The project was completed within a budget of $150,000 in DARPA-provided funds and CALSTART-generated matching funds, which were indicated by unaudited financial statements to be slightly over $257,000. No additional funding was requested or received.

5.1 Cost overruns No cost overruns were incurred. The initial operating budget was just under $20,000/month for all PHA expenses. Initial revenue projection was $23-24,000/month. The monthly operating budget was later revised to $18, 883 as experience was gained in actual costs incurred. Revenue projections were reduced, based on actual fees collected from resident PHA companies and external sponsorships actually received, to $15,600/month early in CY97. Expenses were further reduced to a budgeted $15,050. Unaudited financials indicate that FY97 income covered this level of expense.

6. **<u>Conclusions</u>** The impact of this project has occurred in two distinct areas: 1) Successful implementation of the first civilian re-use of the closing Alameda NAS; 2) Support for the start-up and growth of a business incubator for emerging companies working on advanced transportation technologies or services. Project Hatchery Alameda has demonstrated the capacity for this type of business incubator to be self-financing at certain definable levels and mixes of occupancy. While these levels have been demonstrated and are achievable, two cautionary elements have been identified: 1) the apparent requirement for a sustainable marketing, recruitment, and screening plan that does not require large time commitments from a permanent staff of 1.5 FTE; 2) a properly functioning technology incubator is penalized for its success in moving companies into the marketplace by an immediate gap in cash flow. This argues for some level of sustained sponsorship by stakeholders in the process and, in over a year of experience, we have discovered no other incubator without such outside support to help fill the cash flow gaps. This support usually comes from the community, or industry segment, which benefits from the positive economic impact of the incubator tenants and "graduates". Project Hatchery Alameda will continue at least through the term of its lease with the U.S. Navy and ARRA.

6.1 Attachments Attachments to this report include;

1) Outline of Strategic Business Unit Plan
2) Revised workplan for Project Hatchery Alameda
3) PHA Operating Budget and Income (FY97 and FY98)
4) Directory of PHA companies
5) Selection of press coverage and related items

Outline of Strategic Business Unit Plan
Project Hatchery Alameda

Goals

1. Provide an operating environment which supports advanced transportation technology companies from concept to commercial operation.

2. Create high-quality jobs in the region and in the state based on successful growth of these companies.

3. Achieve sustained self-financing status as a business incubator at NAS Alameda.

Objectives

1. Project Hatchery Alameda (PHA) is to serve as a launch pad for 10 to 20 new or emerging transportation technology-related businesses on a continuous basis. This one location will provide inexpensive private office space, with shared access to a fabrication shop floor, machine tools and equipment.

2. Keep the facility full and have a pre-selected waiting list to ensure it will stay occupied. Locating at PHA is to become the preferred decision for qualified companies in the industry based on its excellence and that of its companies.

3. Provide a range of business development services, as further detailed below.

4. Develop and maintain a network of business service providers to support tenants.

5. Operate as a separate strategic business unit within CALSTART. This dictates that revenues from tenants and any other activities developed should cover all PHA operating costs.

6. Achieve self-sustaining financial status within one year of operation.

Functional Description of Project Hatchery Alameda

1. Method of Operation

Government funds and private sector sponsorships are applied to cover hangar conversion and first year start-up costs.

Revenues from tenants to cover ordinary, budgeted annual operating costs. This will require 80% hatchery capacity to cover costs including lease based on experience to date. Hatchery capacity of 60% should cover costs with lease credit for facility improvements.

During the Start-up Phase, other categories of tenants will be accepted if no core business companies are impacted (eg., ACET, Workers to Business Owners) and to provide for revenue. Emphasis is to be on rapid transition to companies which fulfill the Hatchery mandate. This interim plan also benefits base re-use goals in cooperation with the ARRA.

Tenant recruitment is to be an on-going part of the director's role with support of consultants already contracted for this activity. Businesses will be screened by established criteria, advisory committee input, and compatibility with existing tenants.
Leases will be negotiated on a case-by-case basis.

2. Services Provided

PHA plans to achieve its objectives by providing the following services and resources to Hatchery tenants. Some will bear a cost and be assessed as fees above rent. In principal, these will be consistent with the Southern California facility practice.

--Customized business consulting
--Access to high quality industrial machine shop and test equipment for hardware prototype and fabrication
--Dedicated office and shop space for tenants at an all-inclusive rental cost
--Marketing support for commercially viable products/services
--Strategic partner opportunities and introductions
--Business plan development assistance
--Service provider network through Hatchery support associates
--Assistance in identifying capital and funding sources
--Vehicle test area

3. Staffing and Management

PHA staffing is to be lean, with each member having a multi-functional role. Planned staff consists of a Hatchery Director, Office Manager, and a facility maintenance person. The latter will initially be on a contract basis. All required staff are on board as of June '96; no additional staff are planned. The director reports directly to the CALSTART Exec. VP. The director is responsible for facility management, tenant interface including support services and mentoring, and Hatchery business with external agencies such as the ARRA, Navy, etc. The director is also responsible for management of PHA as a CALSTART strategic business unit in concert with corporate goals. The office manager is responsible for the administration of the CALSTART offices and is to be available on an allocated basis, expected to be 25%, to support corporate programs. The maintenance function is paint, polish, repair and prevent outage.

An advisory board will be formed, consisting primarily of private sector members including major sponsors. The board will periodically review policies guiding Hatchery operations , participate in identifying, referring and screening tenant companies, and assist the start-up companies in the incubator.

4. Business Strategy/Path to Sustainability

PHA plans to become a self-financing business unit by the end of the first year of operations: targeted as not later than 1 December 1996. The Hatchery is to continue as a self-supporting activity throughout its life. When completely filled, it has the potential to be a minor but continuing additional revenue source to the corporation. Elements of this strategy include:

1) Two year detail budget has been developed and is to be rationalized against actual expenses and revenues. A near-term goal is to implement a Planned Program Budgeting procedure for PHA operations. Actual expense requirements and charges to PHA budget are to be defined, approved, and tracked.
2) Application of the one-time start-up costs (estimated to be up to $475,000) against master lease costs in accord with provisions of that lease.
3) Full-time director will implement a tenant-capture marketing campaign focused around the Grand Opening and sustained past the 100% occupancy level to develop the pre-qualified waiting list. Intent is to ensure a full Hatchery while planning for tenant turnover as they move to commercialization. Specific tasks include: a) letters of introduction/invitation to companies screened from the CEC TETAP RFP list and, especially, responding proponents, b) follow-up calls by director to key companies that fit Hatchery goals or add to the existing company matrix, c) continued newspaper and TV coverage of Hatchery with emphasis on high profile and commercial milestones such as vehicle production, successful tests, etc., d) personal and company membership in transportation and environmental professional organizations, e) presentations and participation in meetings and conferences.
4) Consultants are under contract to develop additional Hatchery sponsorships. PHA director will continue to make contacts and presentations to potential sponsors. A program to better recognize and reward sponsorship is to be evaluated and implemented if it looks good.
5) A unique situation exists at Project Hatchery Alameda: the potential for a full-scale outdoor test, demonstration and development area for alternate fuel vehicles. The east-west runway, taxiways and hardstand of the deactivated airfield are excellent for vehicle test and demonstration. At this time, the window of opportunity is opening for continued use of the airfield for these activities. As a minimum, this is a significant attraction for companies to locate here. As a preferred alternative, it would be an on-going source of revenue to have and manage a vehicle test track/skid pad/proving ground. Advertising the availability of such a facility will attract new tenants, whether they have an immediate need for a test track or not.

5. Relationship to CALSTART Core Competencies

Operation and management of Project Hatchery Alameda according to the plan outlined will help tenant companies through application of key CALSTART core competencies to their business , including:

1) Identification of funding sources for advanced transportation projects/programs
2) Proposal writing
3) Technology evaluation, dissemination and exposure
4) Strategic partnering, including synergy within the incubator
5) Networking
6) Market identification and analysis for specific technologies and end products
7) Prototype vehicle and infrastructure funding, development and demonstration

J. J. Huetter/19 July 1996

Project/Task	Due Date	Comp Date		Personnel TOTAL	20% Admin NA	JoB	JiB	50% Admin AB	CB	100% Admin SC	AC	100% Admin WD	EE	50% Admin MG	NG
Business Unit: PH Alameda															
REQUIRED PERSON DAYS				193.0		5.0		4.0							
AT RISK PERSON DAYS			common fees / ARPA RA 94 / Agile												
Goal 1: Remain self-sustaining unit			common fees / ARPA RA 94 / Agile												
Objective 1: 100% occupancy rate			common fees / ARPA RA 94 / Agile												
Task 1: Market PHA facility	9/30/97		common fees / ARPA RA 94 / Agile	17.0											
Task 2: Maximize free media coverage	9/30/97		common fees / ARPA RA 94 / Agile	12.0											
Task 3: Promote PHA at conferences and meetings	Monthly		common fees / ARPA RA 94 / Agile	9.0		3.0									
Goal 2: Finance, or equivalent funds for one or more PHA companies															
Objective 2.1: Identify and develop finance sources for PHA level firms			common fees / ARPA RA 94 / Agile												
Task 2.1.1: Initial listing of current funding/finance sources	1/31/97	1/31/97	common fees / ARPA RA 94 / Agile	1.0											
Task 2.1.2: Listing and timing of PHA firms financing requirements	1/31/97	3/30/97	common fees / ARPA RA 94 / Agile	2.0											
Task 2.1.3: Introduction, brokering or financing product or R&D	6/30/97		common fees / ARPA RA 94 / Agile	7.0		1.0									
Objective 2.2 Work with team to develop CALSTART capital fund			common fees / ARPA RA 94 / Agile												
Task 2.2.1: Search for capital	1/17/97		common fees / ARPA RA 94 / Agile	2.0											
Task 2.2.2: Identify, screen, select capital fund management	3/1/97		common fees / ARPA RA 94 / Agile												
Task 2.2.3: Implement a placement through/from CALSTART fund	7/30/97		common fees / ARPA RA 94 / Agile	1.0											
Goal 3: Evaluate and implement available opportunities to expand PHA into another facility on a self-sustaining basis			common fees / ARPA RA 94 / Agile												
Task 3.1; Identify and qualify NAS facilities for potential expansion	1/31/97	2/14/97	common fees / ARPA RA 94 / Agile												
Task 3.2: Negotiate terms/execute lease with ARRA	4/30/97	Cancel	common fees / ARPA RA 94 / Agile												
Task 3.3: Secure funding for facility rehabilitation and retrofit	4/30/97	Cancel	common fees / ARPA RA 94 / Agile												
Task 3.4: Manage rehab contracts	9/30/97	Cancel	common fees / ARPA RA 94 / Agile												
Task 3.5: Identify, screen and recruit appropriate technology tenants	11/15/96	1/31/97	common fees / ARPA RA 94 / Agile												
Goal 4: Expand an active service provider network for PHA			common fees / ARPA RA 94 / Agile												
Task 4.1: Identify and solicit PHA service providers/associates	11/15/96		common fees / ARPA RA 94 / Agile	3.0											
Task 4.2: Announce and schedule associate sessions/seminars/FAC	Monthly		common fees / ARPA RA 94 / Agile	3.0											
Task 4.3: Presenting associate sessions and seminars	Monthly		common fees / ARPA RA 94 / Agile	3.0											
Task 4.4: Assistance/consulting	9/30/97		common fees / ARPA RA 94 / Agile	4.0											
Goal 5: Improve PHA value			common fees / ARPA RA 94 / Agile												
Objective 5.1: Secure rights for EV and AFV test/demonstration area			common fees / ARPA RA 94 / Agile												
Task 5.1.1: ID areas for test track	1/6/97	1/6/97	common fees / ARPA RA 94 / Agile												
Task 5.1.2: Negotiate w/Navy, ARRA, other agencies as required	4/18/97	3/21/97	common fees / ARPA RA 94 / Agile	7.0		1.0		2.0							
Task 5.1.3: Develop testing SOPs, schedule and fees, and use plan	3/31/97		common fees / ARPA RA 94 / Agile	3.0											
Objective 5.2: Maintain and Improve Facility Efficiency and Capability			common fees / ARPA RA 94 / Agile												
Task 5.2.1 Keep machine shop functional, used and maintained	9/30/97		common fees / ARPA RA 94 / Agile	12.0											
Task 5.2.2: Install EV Chargers	12/20/96	1/31/97	common fees / ARPA RA 94 / Agile												

Project/Task																					
		20%				100%		100%		40%					100%						
		Admin				Admin		Admin		Admin					Admin						
Business Unit: PH Alameda	PH	JiH	JoH	ML	GL	AM	TN	JP	MP	GIP	GrP	NP	SR	MS	VS	DS	IS	WT	EV	BVA	LW
REQUIRED PERSON DAYS			116.0																	2.0	
AT RISK PERSON DAYS																					
Goal 1: Remain self-sustaining unit																					
Objective 1: 100% occupancy rate																					
Task 1: Market PHA facility			12.0																		
Task 2: Maximize free media coverage			10.0																	2.0	
Task 3: Promote PHA at conferences and meetings			6.0																		
Goal 2: Finance, or equivalent funds for one or more PHA companies																					
Objective 2.1: Identify and develop finance sources for PHA level firms																					
Task 2.1.1: Initial listing of current funding/finance sources			1.0																		
Task 2.1.2: Listing and timing of PHA firms financing requirements			2.0																		
Task 2.1.3: Introduction, brokering or financing product or R&D			6.0																		
Objective 2.2 Work with team to develop CALSTART capital fund																					
Task 2.2.1: Search for capital			2.0																		
Task 2.2.2: Identify, screen, select capital fund management																					
Task 2.2.3: Implement a placement through/from CALSTART fund			1.0																		
Goal 3: Evaluate and implement available opportunities to expand PHA into another facility on a self-sustaining basis																					
Task 3.1; Identify and qualify NAS facilities for potential expansion																					
Task 3.2: Negotiate terms/execute lease with ARRA																					
Task 3.3: Secure funding for facility rehabilitation and retrofit																					
Task 3.4: Manage rehab contracts																					
Task 3.5: Identify, screen and recruit appropriate technology tenants																					
Goal 4: Expand an active service provider network for PHA																					
Task 4.1: Identify and solicit PHA service providers/associates			3.0																		
Task 4.2: Announce and schedule associate sessions/seminars/FAC			3.0																		
Task 4.3: Presenting associate sessions and seminars			3.0																		
Task 4.4: Assistance/consulting			4.0																		
Goal 5: Improve PHA value																					
Objective 5.1: Secure rights for EV and AFV test/demonstration area																					
Task 5.1.1: ID areas for test track																					
Task 5.1.2: Negotiate w/Navy, ARRA, other agencies as required			4.0																		
Task 5.1.3: Develop testing SOPs, schedule and fees, and use plan			3.0																		
Objective 5.2: Maintain and Improve Facility Efficiency and Capability																					
Task 5.2.1 Keep machine shop functional, used and maintained			12.0																		
Task 5.2.2: Install EV Chargers																					

Project/Task Business Unit: PH Alameda	100% Admin SW	SZ	E1	A1	W1
REQUIRED PERSON DAYS		66.0			
AT RISK PERSON DAYS					
Goal 1: Remain self-sustaining unit					
Objective 1: 100% occupancy rate					
Task 1: Market PHA facility		5.0			
Task 2: Maximize free media coverage					
Task 3: Promote PHA at conferences and meetings					
Goal 2: Finance, or equivalent funds for one or more PHA companies					
Objective 2.1: Identify and develop finance sources for PHA level firms					
Task 2.1.1: Initial listing of current funding/finance sources					
Task 2.1.2: Listing and timing of PHA firms financing requirements					
Task 2.1.3: Introduction, brokering or financing product or R&D					
Objective 2.2 Work with team to develop CALSTART capital fund					
Task 2.2.1: Search for capital					
Task 2.2.2: Identify, screen, select capital fund management					
Task 2.2.3: Implement a placement through/from CALSTART fund					
Goal 3: Evaluate and implement available opportunities to expand PHA into another facility on a self-sustaining basis					
Task 3.1; Identify and qualify NAS facilities for potential expansion					
Task 3.2: Negotiate terms/execute lease with ARRA					
Task 3.3: Secure funding for facility rehabilitation and retrofit					
Task 3.4: Manage rehab contracts					
Task 3.5: Identify, screen and recruit appropriate technology tenants					
Goal 4: Expand an active service provider network for PHA					
Task 4.1: Identify and solicit PHA service providers/associates					
Task 4.2: Announce and schedule associate sessions/seminars/FAC					
Task 4.3: Presenting associate sessions and seminars					
Task 4.4: Assistance/consulting					
Goal 5: Improve PHA value					
Objective 5.1: Secure rights for EV and AFV test/demonstration area					
Task 5.1.1: ID areas for test track					
Task 5.1.2: Negotiate w/Navy, ARRA, other agencies as required					
Task 5.1.3: Develop testing SOPs, schedule and fees, and use plan					
Objective 5.2: Maintain and Improve Facility Efficiency and Capability					
Task 5.2.1 Keep machine shop functional, used and maintained					
Task 5.2.2: Install EV Chargers					

Project/Task	Due Date	Comp Date	Personnel	TOTAL	NA (20% Admin)	JoB	JIB	AB (50% Admin)	CB	SC (100% Admin)	AC	WD (100% Admin)	EE	MG (50% Admin)	NG
Business Unit: PH Alameda															
Task 5.2.3: Reconfigure and upgrade facility for evolving tenant use/re-use	9/30/97		common fees / ARPA RA 94 / Agile	81.0											
Goal 6: Co-sponsor Alameda International EV Expo	9/28/97		common fees / ARPA RA 94 / Agile	26.0				2.0							

Project/Task																					
		20%				100%		100%		40%					100%						
		Admin				Admin		Admin		Admin					Admin						
Business Unit: PH Alameda	PH	JiH	JoH	ML	GL	AM	TN	JP	MP	GIP	GrP	NP	SR	MS	VS	DS	IS	WT	EV	BVA	LW
Task 5.2.3: Reconfigure and upgrade facility for evolving tenant use/re-use			28.0																		
Goal 6: Co-sponsor Alameda International EV Expo			16.0																		

Project/Task	100% Admin SW	SZ	E1	A1	W1
Business Unit: PH Alameda					
Task 5.2.3: Reconfigure and upgrade facility for evolving tenant use/re-use		53.0			
Goal 6: Co-sponsor Alameda International EV Expo		8.0			

PROJECT HATCHERY ALAMEDA FY 97 BUDGET (REVISED)

EXPENSES		INCOME	
Utilities	$47,905	Tenant Fees (Current and expected)	$192,200
Services	$21,550		
Supplies	$14,700	Tenant Reimbursements	$3500
Equipment (Leases and Maintenance)	$18,515	Foundation/Corporate Funding Assistance	$10,000
Travel Allowance	$1400		
Insurance	$5040		
Direct Labor	$102,300		
Overhead	$25,575		
Facility Maintenance	$2400		
Total Expenses:	$239,385	Total Revised Income:	$196,700

PROJECT HATCHERY ALAMEDA FY 98 BUDGET (Projected)

EXPENSES		INCOME	
Utilities	$48,000	Tenant Fees	$220,000
Services (Includes Marketing Program)	$41,550	Tenant Reimbursements	$3600
Supplies	$14,000		
Equipment	$18,515	Foundation/Corporate Funding Assistance	$50,000
Travel Allowance	$1500		
Insurance	$5040		
Direct Labor	$110,000		
Overhead	$27,500		
Facility Maintenance	$5000		
Total Expenses:	$271,105	Total Projected Income:	$273,600

CONFIDENTIAL INTERNAL DOCUMENT

11 November 1996

FY 97 Project Hatchery Alameda Budget

The following expense budget for operation of the CALSTART business incubator at NAS Alameda for FY 97 is based on historical costs, contracted amounts, and allowances for expenditure in selected categories. All expenses are monthly.

Utilities

Water/Sewer (Historical)		$500
Electric power (Historical)		$2000
Propane (Historical)		$667
Phone/FAX (Historical)		$325
	Subtotal:	$3492

Services

Trash pick-up (Historical)		$165
Facility maintenance (Allowance)		$200
Temporary help (Allowance)		$112
Security (Contract amount)		$200
Janitorial (Contract amount)		$1450
	Subtotal:	$2127

Supplies

Facility consumables (Allowance)		$400
Office (Historical incl. CS/North)		$400
Postage/Courier (Historical)		$70
Copies (Historical)		$120
Periodicals (Allowance)		$35
Unlisted items (Allowance)		$200
	Subtotal:	$1225

Equipment

Equipment leases (Contract amount)		$650
Equip't. Maintenance (Contract amount)		$168
Machine shop O&M (Allowance)		$200
Safety/Training (Allowance)		$100
	Subtotal:	$1118

Personnel

Direct labor (incl. 3% escalation per JP)	[redacted]
Overhead @ 25%	[redacted]
Facility maintenance person (Allowance)	$1408
Travel	$100
Subtotal:	[redacted]

Insurance

Allocated CGL and Property	$334
Workers Comp	$86
Subtotal:	$420
TOTAL:	$19,757

CALSTART

A California Non-Profit
Consortium Developing
Advanced Transportation
Technologies

Project Hatchery Alameda Directory

Company Name	Phone No.	Contact Person	Description
Alameda Center for Environmental Technologies	510-263-9874 fax: 263-0261	**Joan Michlin**, Office Mgr. **Sam Doctors**, CEO	*Developing an incubator for environmentally related companies*
Altamont Technologies, Inc.	510-865-6533 415-921-7477	**Richard Farrell,** President	*Development of fuel-effcient, lightweight, monocoque composite transport modules*
CALSTART	510-864-3006 fax: 864-3010	**John Huetter,** Director, Project Hatchery	*Non-profit consortium developing advanced transportation technologies*
Clean Air Products Technology	510-864-3160 fax: 864-3159	**Tim Perry,** President	*Develop and fabricate process clean-up and recycling equipment*
Datronics	510-864-3150 fax: 864-3151	**Walt Day,** CEO	*Design, develop and prototype unique electric "Power-lift Wheelchair".*
EBCRC-Workers to Business Owners Project	510-864-3152 fax: 864-3154	**Pam Calloway** Project Coordinator	*Helping former base workers develop their own businesses.*
Forem Metal Manufacturing	510-864-8102 fax: 864-8125	**Roland Maynard,** Production Manager	*Truck body modifications to increase payload and access.*
Franklin Environmental	510-864-3190 fax 864-3192	**Carlos Franklin,** President	*Environmental products for wastewater, remediation, and oil spill clean-ups.*
Green Motorworks	510-521-4300 fax: 864-3010	**Bill Meurer,** President **Bob Reese**, Bay Area Mgr.	*Conversions to electric vehicles. Electric vehicle sales, leases, and service.*
HORNET Foundation	510-521-8448 fax: 521-8327	**Ralph Johnson,** Treasurer	*Preserve and operate the U.S.S. HORNET as a floating museum and base re-use facility.*
Jefferson Programmed Power	510-865-0672 fax: 865-0673	**Lee Ackerson,** General Manager	*Developing and producing high power DC controllers for electric vehicles.*
Kaylor Energy Products	510-521-8887 fax: 864-3010	**Roy Kaylor,** President	*Designers & manufacturers of hybrid and electric conversion kits and vehicles.*
Kummerow Corp. of North America	818-565-5688	**Hans Kummerow** President	*Development and assembly of high energy density zinc-air batteries for bus and truck fleets.*
Phasor Corporation	510-686-1788 fax: 284-9442	**Bruce Colley** President	*Design and development of electric and hybrid electric vehicle components.*
Procyon Power Systems	510-864-3179 fax: 864-3180	**Gary Noland,** President	*Development of a hybrid vehicle engine based on a reactor/fuel cell.*
Waste Energy Integrated Systems	415-858-2114	**Chuck Lombard** President	*Research,design, and production of ethanol fuel from waste products.*
Zebra Motors	510-864-3200 fax: 864-3010	**Larry Stadtner,** President	*Development and manufacture of high-performance electric sports cars.*

Updated: September 8, 1997

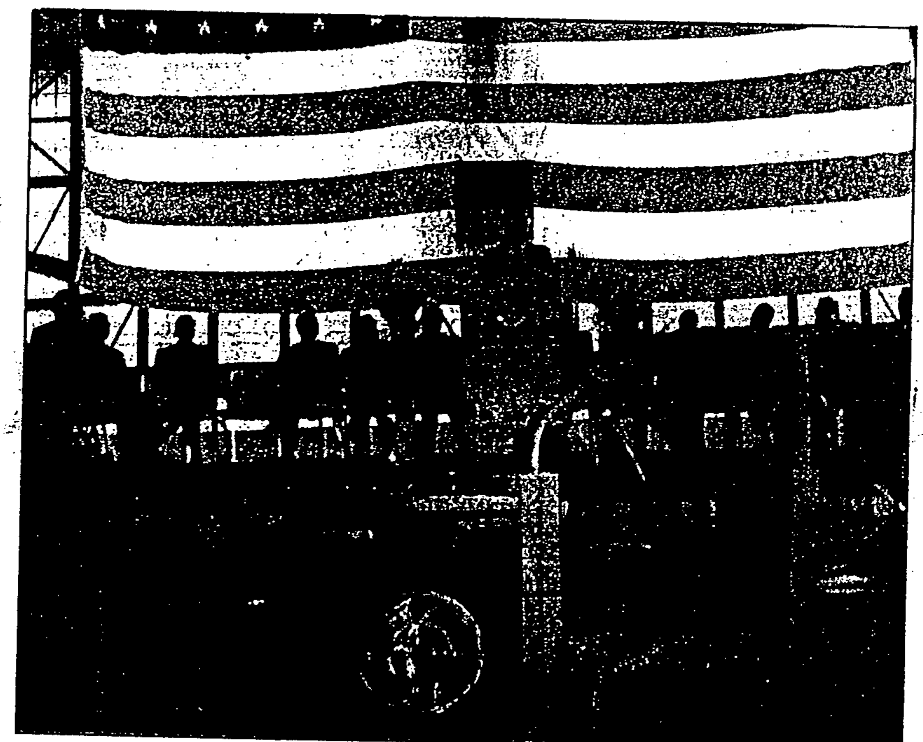
The Oakland Tribune.

November 11, 1995

Planes, brains and electric automobiles

Officials find new hope for base

By Kathleen Kirkwood
STAFF WRITER



JIM STEVENS — Staff

Lon Bell, president of Amerigon, addresses the crowd during Friday's lease-signing ceremonies at NAS. Amerigon will manufacture electric cars such as the one in the foreground at NAS.

ALAMEDA — A hangar that sheltered the Navy's state-of-the-art aircraft for 54 years officially shifted gears on Friday, becoming home to cutting-edge electric car technology.

Top defense officials ushered in a CALSTART transportation hub at Alameda Naval Air Station that marks the first civilian toehold at the closing base.

Navy, city and company executives gathered in the cavernous hangar to sign leases and turn over the keys.

It means CALSTART, a statewide consortium of 165 agencies and companies, can start using the 65,000-square-foot building immediately.

Three electric cars from competing CALSTART companies were driven in for the ceremony, dwarfed by a minesweeping helicopter and Navy jet parked in the hangar.

CALSTART's new Project Hatchery North for alternative transportation companies will provide an estimated 50 jobs in the next six months, led by anchor tenant Amerigon Inc.

"Some good, high-paying jobs will happen right away and the possibility of many more in the near future exists," said Mike Gage, president and chief executive officer of CALSTART.

Amerigon and CALSTART were lured by $2.9 million in defense and federal transit matching grants, engineered by Rep. Ron Dellums, D-Oakland.

Setting up shop in the hangar, on the edge of the base's airfield, means a dramatic change for both the base and the community, said Deputy Assistant Secretary of the Navy William J. Cassidy Jr.

Cassidy told about 200 officials at the event that he had just finished touring several of the nation's 171 military installations that are undergoing closure or realignment, such as Long Beach Naval Shipyard and the Philadelphia Naval Shipyard.

"These bases across the country have served the nation so well that they have become part of the social fabric of communities," Cassidy said.

The CALSTART hub means the base will now "project America's economic might across the world just as the Naval Air Station for so long, 50 years, projected America's might across the globe," said Cassidy.

Amerigon's president, Lon Bell,

Please see **Base,** A-9

Base: Deal may mean new life, jobs

Continued from A-1

said the all-aluminum chassis made by his company for electric vehicles represents a marriage of industry and defense technology, including assistance from Lawrence Livermore National Laboratory.

Cutting-edge technology is now "sitting on the shelf," said Bell. Electric and alternative vehicles represent a new front in economic wars, said Bell, alluding to Japan's progress in the area.

"It is up to us to take these resources and now apply them for a new battle that we are going through, a global economic battle," said Bell.

Along with Amerigon, the new hub has three other start-up tenants: Green Motorworks, Jefferson Programmed Power and U.S. Electric Car.

The base is due to close in April 1997, and the lease with CALSTART is a symbolic boost to local efforts to replace 3,000 lost jobs.

"We have come a long way since that day they announced the base would close," said Alameda Mayor Ralph Appezzato.

Just last month, the city lost a top contender to bring jobs to a 100,000-square-foot building at the base, AEG Transportation Systems.

Now, however, it looks like CALSTART may lure a Norwegian company that could occupy the space that AEG had targeted. The firm, PIVCO of Norway, wants to bring both assembly lines and a showroom to sell electric cars at the site, said Kay Miller, reuse agency executive director.

Getting the leases — one between the Navy and the Alameda Reuse and Redevelopment Authority and another between the reuse agency and CALSTART — hasn't been easy, and has involved several players, said Paul Dempsey, the director of the Office of Economic Adjustment.

ALAMEDA BASE IN TRANSITION

EXAMINER/BOB MCLEOD

Dignitaries offer *speeches full of hope at ceremony Friday for the first commercial site at Alameda Navy base.*

Civilians begin takeover at converted air station

Companies needed to fill economic void to be left by departure of Navy

By Michael Dougan
OF THE EXAMINER STAFF

ALAMEDA — A tiny blue electric car was parked next to a giant Marines helicopter in Alameda Naval Air Station's Hangar 20 Friday afternoon, symbolizing the start of the base's conversion to civilian use.

In a ceremony featuring 11 optimistic speeches, Hangar 20 became the first commercial site at the air base since it opened in 1941. Next week, the 70,000-square-foot hangar will be a factory producing electric automobiles.

Only 20 to 40 people will be employed initially, said Michael Gage, president and CEO of CALSTART, the nonprofit consortium of California companies that signed an agreement Friday to lease the hangar.

But local officials hope this is just the start of the creation of thousands of new jobs at the 2.5 million-square-foot naval base — set to close by late 1997.

It's been estimated that closure of the air station and related facilities could wipe out almost 5 percent of all jobs in the Oakland metropolitan area.

Next year, Gage said, the consortium might hire hundreds and, in the years ahead, thousands of people to work for civilian firms who have set up at the former Navy base.

CALSTART, a consortium of aerospace and high-tech firms, transit and public agencies, labor and environmental groups, functions to create advanced transportation technologies in the state.

Three companies will use Hanger 20 to construct electric cars, including the City Bee, a zippy two-seater just over 9 feet long. An electrified Geo and a chassis with no body — designed for export — were also on display Friday.

Even as the civilian companies

[*See ALAMEDA, A-9*]

ALAMEDA from A-1

Alameda NAS takes first civilian step

start their operations, the air station will continue to support two nuclear aircraft carriers and a helicopter squadron, said Capt. Jim Dodge, commanding officer of the base.

He said logistical and security problems stemming from joint military and civilian use of the air station would be minimal.

Although the first phase of the base's conversion appears modest, Paul Dempsey, director of the Department of Defense's Office of Economic Adjustment, said at the lease signing that long-term economic prospects are "outstanding."

"The focus from the beginning of this program has been to directly benefit the workers," he said.

Dempsey announced the approval of $750,000 in grants for East Bay communities to help workers make the transition.

"Closing bases is very difficult, it is painful," said William Cassidy, deputy assistant secretary of the Navy. But, "people are not looking back, they're looking forward."

Mayor Ralph Appezzato said the ceremony marked "the first day of a new future for Alameda. We will succeed in converting this base to a civilian economy."

Under terms of the new agreement, the military has leased Hangar 20 to the Alameda Reuse and Redevelopment Authority, an organization formed to implement the civilian takeover of the base. The authority, in turn, has sublet the hangar to CALSTART.

Sunday, May 5, 1996

San Francisco Examiner

Picking Up Speed

State's electric car industry not stalled by regulation changes

By Scott Coch
MEDILL NEWS SERVICE

The state's decision this spring to roll back electric car quotas might have easily crushed California's nascent electric vehicle industry. But it didn't.

The state Air Resources Board on March 29 unanimously stripped a 1990 requirement that car manufacturers make 2 percent of all California-sold cars exhaust-free by 1998. The quota would expand to 5 percent of all California cars by 2001 and 10 percent by 2003.

Instead of the quota, the "big seven" car-makers — General Motors, Ford, Chrysler, Toyota, Nissan, Honda and Mazda — agreed to put a combined total of 800,000 electric cars on California roads by 2010.

California's investment in electric cars is substantial. Industry insiders estimate that the state accounts for about 2,000 alternative-fuel vehicle jobs, about 300 companies and about half a billion dollars worth of research and development

Considering the stakes, the lifted mandate could have spelled disaster. What might have been a death blow a few years ago, however, is now just a small bump in the electric vehicle's road, apparently. To hear industry people tell it, the electric car industry has achieved escape velocity from the car show and is well on its way into mainstream traffic.

"It's starting to have a momentum of its own," said Bill Van Amburg, communications director for Burbank-based CalStart, a non-profit consortium of about 300 alternative fuel-vehicle-related companies in California.

Van Amburg insisted that the abolished mandate "hasn't hurt the industry," but allowed that defanging the state regulation has produced "a change in the landscape."

He pointed to recent, electrically powered offerings by established automakers as evidence that the movement toward electric vehicles have reached a critical mass of viability and market visibility.

In early April, both the American Honda Motor Company and Toyota Motor Sales USA announced plans to put electrically powered cars on the road in California by 1998. Both cars will use nickel-metal hydride batteries, which allow cars to roam much farther afield than cars dependent on traditional lead acid batteries.

Citing the high cost of the advanced battery packs, however — the batteries to be used in the 1998 cars have been estimated to cost tens of thousands of dollars — car companies cried poverty to the state.

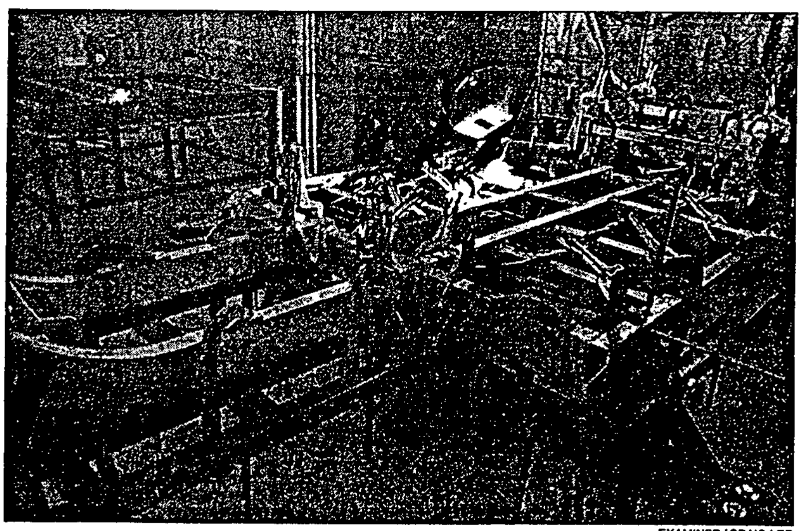
If they were forced to sell electric cars by the state's initial deadline, car makers said, they would have to be fitted with inefficient, range-limiting lead acid batteries. Consumers accustomed to gasoline cars, the argument ran, would sour on the electric car before the new batteries could be phased in, poisoning public opinion against the whole concept.

For companies already offering complete electric cars, however, the news that most big American carmakers won't be plugging into the electric market en masse right away is welcome.

"In a nutshell, it's very good news for us," said Bill Meurer, president of North Hollywood-based Green Motorworks. "We'll be able to get a higher price for our vehicles."

EXAMINER / ELIZABETH MANGELSDORF

Ready to roll: *U.S. Electricar CEO Roy Kusumoto shows off one of his S.F. company's latest models.*



EXAMINER / CRAIG LEE

Assembly required: *A frame for an electric car is welded together at Amerigon in Alameda.*

In business since 1991 and in the black since last January, Motorworks imports electric cars and converts gasoline-engined vehicles ranging from station wagons to sports cars.

Some companies had seen the quota climb-down coming years ahead of time.

"Our company was not at all immediately affected," said Joshua Newman, a spokesman for Amerigon, a electric car company in Monrovia in Los Angeles County.

The 4½-year-old company, which employs more than 60 people in its electric car design services and electric car and car parts manufacturing divisions, recently began production in a former Naval Air Station Alameda building.

"Our strategy was re-oriented away from the United States several years ago," Newman said. "It was clear ... that the car companies were going to fight (the mandate) strongly, and that the oil firms were going to join them."

Since then, Amerigon has focused on exporting to India, China and Southeast Asia. Explosive growth in the auto markets of developing nations, combined with high demand for non-polluting urban vehicles and lack of political opposition, Newman said, make overseas markets more attractive than American markets anyway. The low single-digit growth of the U.S. auto market, he said, pales next to the roughly 15 percent annual growth seen in electric vehicle markets abroad.

"Speaking for the industry as a whole, the reduction of the mandate ... has, in my opinion, slowed the growth of the U.S. market (for electric car)," Newman said.

Newman said he was distressed that just a few months after carmakers told the board that battery technology wasn't advanced enough to market, both Toyota and Honda announced that their 1998 electric cars would have the new batteries.

While stopping short of calling the car-makers liars, Newman contended that, "The battery technology was considerably more advanced than was represented to the Air Resources Board."

Robert Bienenfeld, manager of Honda's Alternate Fuel Task Force in Torrance, insisted that "we really didn't hold anything back" in discussion with the board and battery makers.

As a result of the lifted mandate, Honda will now only have to make 300 cars over the next three years, instead of being forced to produce 2,500 electric cars per year from 1998 to 2001.

"Our studies showed that there was a very limited market for the cars with the limited range that lead acid batteries could deliver," Bienenfeld said.

San Francisco-based U.S. Electricar, on the other hand, was hit hard, albeit indirectly, by perceptions that 1994's congressional sea change and the rising tide of Republicans in the statehouse augured ill for the state quotas.

"It put a general chilling effect on the entire industry," said John Micek, Electricar's CEO. Potential investors he said, were frightened, and, "Everybody kind of backed off."

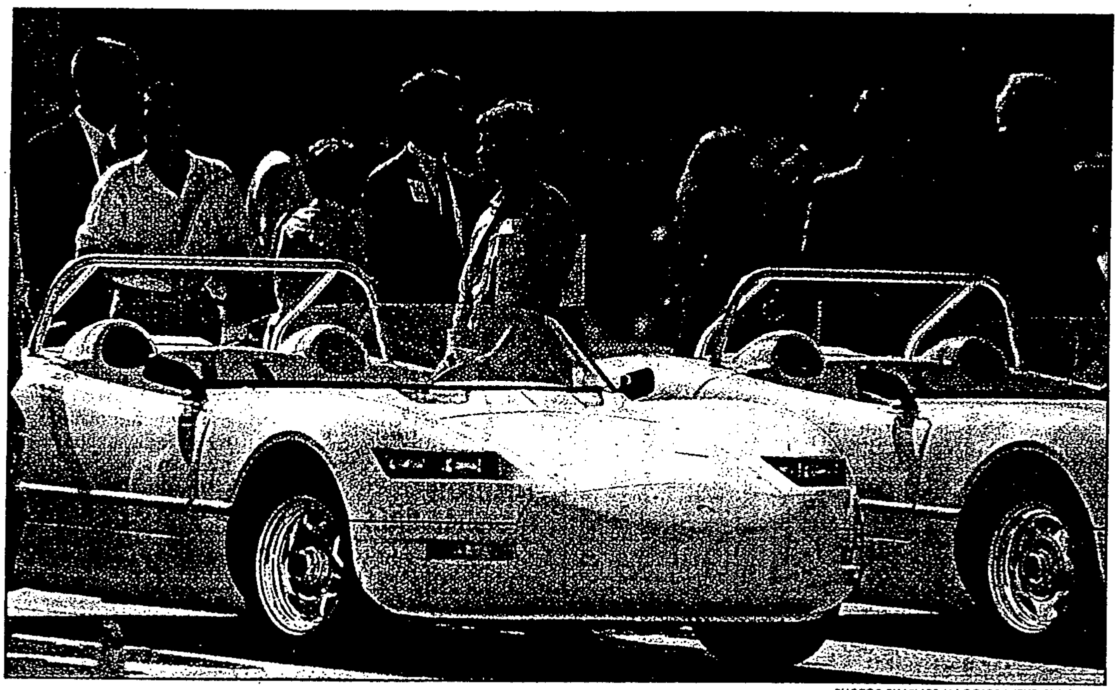
Although the company's emphasis is on commercial vehicles, Micek said, Electricar had to slash its workforce from 300 to 75 people over the past year, and is currently in negotiations with creditors to restructure its debt.

Micek predicted Electricar will expand once again, but focused mostly in markets in Mexico and Asia.

"We think that the pall has lifted," he said. "We think the market is there."

San Francisco Chronicle

TUESDAY, JULY 23, 1996



PHOTOS BY VINCE MAGGIORA/THE CHRONICLE

Zebra Motor Inc. of Novato showed off its two-seat electric sports car at the Alameda Naval Air Station

An Electrifying Conversion

Clean transportation startups hatched at Alameda air station

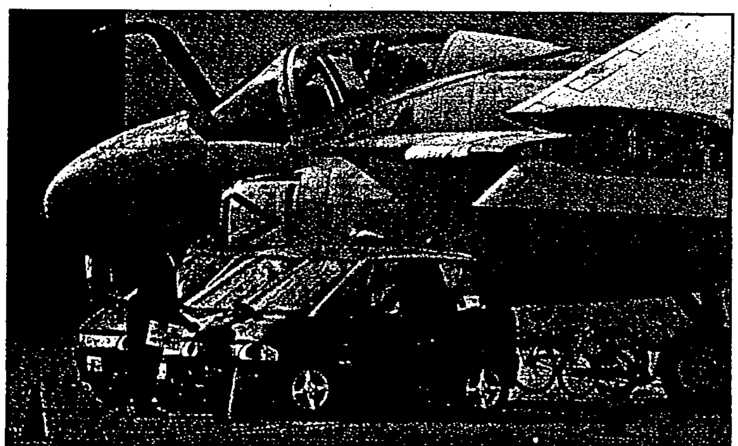
By Jonathan Marshall
Chronicle Economics Editor

Looking out on million-dollar views of San Francisco and the Bay, dozens of government officials, engineers and curious citizens zipped around the Alameda Naval Air Station airfield yesterday in electric cars.

The occasion was the first open house of a business incubator center housing eight small companies in the clean transportation field. These startups are pioneering the conversion of the 1,842-acre Alameda Naval Air Station to civilian uses, before the Navy finishes its pullout next April.

Located at the air station's Hangar 20, the center was opened only about six months ago with the help of a $2.5 million federal grant from Calstart, a nonprofit consortium dedicated to advancing transportation technology in California.

Already the incubator employs 50 and is three-quarters leased. An A-6 Intruder aircraft parked just outside, with its wings folded, is the only reminder that military jets were once housed in the 65,000-square-foot space.



Electric cars were parked next to an A-6 Intruder at the air station

"Just a few months ago this hangar was empty and the mood was solemn," said Alameda Mayor Ralph Appezzato. "Thanks to Calstart we have a hangar full of vibrant activity, full of hope and optimism."

The idea behind business incubators is to create synergies by putting small companies in the same industry side by side.

Calstart has created a similar business incubator for clean transportation companies in its hometown of Burbank. That site now has 25 businesses.

Michael Gage, president of Calstart, said both should prove viable. "Alameda can become a center and prestige address for the advanced transportation technologies industry," he said.

The U.S. Defense Department has helped fund some of the technology that was on display at yesterday's open house.

Thanks to a grant from the Defense Department, engineer Lee Ackerman, who works out of the hangar, just perfected a DC-motor controller that could slash the cost of high-performance electric vehicles. He's close to signing a sales agreement with Zebra Motor Inc. of Novato, which gave participants at the open house high-speed test drives of its snazzy, two-seat sports car.

Zebra also may relocate to the naval air station, but is considering incentive

ELECTRIC: *Page C5 Col. 1*

ELECTRIC: Station's Conversion

From Page C1

packages from other California cities, said Gary Starr, who helped found it along with an electric bicycle company, Zap Power Systems of Sebastopol.

Its car, which proved a hit with the crowd, will retail for about $20,000 in full production. It's not the most practical car, Starr conceded, but it's eye-catching and peppy. You may not be able to go 400 miles in the Zebra, he said, "but you should at least have fun for 40 miles."

A more pedestrian-looking two-seater will become available this month to patrons of the Walnut Creek and Colma BART stations, thanks to Green Motorworks, a North Hollywood electric vehicle marketer that has space in the Alameda hangar.

Earlier this year, more than a dozen of its small electric cars were stationed at the Ashby BART station, where they have proven a hit with employees of Sybase and other companies that lease them for local trips. "We don't have enough cars for everyone who wants them," said William Meurer, president of Green Motorworks.

Green's cars will come with dual air bags, travel up to 60 miles per hour and have a range of about 60 miles on a battery charge when they go on sale to the general public next year for about $15,000, Meurer said. For customers with more traditional design tastes, Meurer also had electric conversions of an Alfa Romeo Spyder and a Ford Escort station wagon on display.

With General Motors scheduled to begin selling its sporty, two-seat Impact electric car next year, these and other startup companies in Alameda hope to ride a wave of growing public interest in quiet, nonpolluting vehicles.

But Meurer conceded his firm, and the industry as a whole, needs some breakthroughs in range and cost before electric vehicles will become big sellers. "We cannot provide a replacement for the gas car right now," he said.

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QUIET HUM OF BASE REUSE

Photo by Kathy Baker

Jeff Gile, an Alameda High School graduate who is now vice president of engineering for Zebra Motors Inc., (in passenger seat) accompanies a visitor for a test drive of his company's nearly silent electric sports car at the CALSTART open house July 22. The event celebrated the establishment of the advanced transportation technologies "hatchery" at Naval Air Station Alameda.

CALSTART hatchery 'just the beginning' at base

By David Quigg
Staff Writer

The engine driving base redevelopment is almost silent, but that doesn't mean it's not working.

With a couple dozen electric hatchbacks, convertibles and sedans decorating its working factory, the CALSTART "advanced transportation technology" consortium welcomed civic, business and government leaders and the press to its home in an old aircraft hangar at Naval Air Station Alameda.

CALSTART Chief Executive Officer and President Michael Gage told about 200 visitors to the hangar that his fledgling industry is unlikely to cluster in one place like the auto industry did in Detroit, but he expects big things in Alameda.

"This is just the beginning," he said. "It is our strong belief that the Alameda Naval Air Station can become ... a prestige address for the advanced transportation technology industry."

CALSTART has only been at NAS since last November, when it became the first private tenant of the base reuse effort. Since then, the consortium has rented 70 percent of the 70,000-square-foot hangar to various start-up companies.

The media buzzed around the City Bee electric car.

Termed a "hatchery," CALSTART's hangar is a place where these firms can try to make dreams of transportation innovation come true. So far, eight hopeful companies have brought 50 jobs to the base.

NAS Commanding Officer Capt. Jim Dodge predicted "more CALSTARTs and more opportunities" for the base.

Many credited Rep. Ron Dellums, D-CA, for hatching the hatchery at NAS. Sandré Swanson, who represents Dellums on the Alameda Reuse and Redevelopment Authority, said the entire effort prior to NAS's 1997 closure should show the rest of the country "you can breathe life into a base before it is closed."

Mayor Ralph Appezzato said he felt a new sense of hope in CALSTART's hangar.

"The future of our community is very bright indeed," he said. "... Just a few months ago this hangar was empty and there was no cause for joy and celebration ... We will succeed in converting this historic base into an economic engine that we in the region can all be proud of."

Another sort of engine was humming almost inaudibly shortly after the mayor's speech. Appezzato took the Zebra Model Z out for a test drive. The Novato company that makes the sleek convertible electric sports car is considering a move to CALSTART's hatchery.

Appezzato was enthusiastic after his brisk spin.

"Those who can afford to purchase an electric vehicle should," he said. "They

see CALSTART, page 12

CALSTART

continued from page 1

look like and feel like you're driving a sports car."

Calling the vehicles ideal for the island, he had similar optimism for the hatchery.

"This is a concrete example that this air station can be productive and can be an economic rebirth for the region," he said, adding that the hatchery need not have a perfect record with the firms it brings to the island. "If just one succeeds, it will be a success."

Reuse authority Executive Director Kay Miller said she expects CALSTART's hatchlings to expand to other base facilities as they grow. She added that her office likes the hatchery concept and is interested in using it again with biotechnology, environmental, telecommunications and motion picture companies.

"We think this is a perfect model for the kind of things we'd like to expand upon here," she said.

Spotlight PG&E August 1996

News for the Customers and Communities We Serve

IN THIS ISSUE • PG&E, PART OF THE ECONOMIC COMMUNITY • TREES, POWER LINES, AND YOU • NEW PG&E UNIFORMS • ORIENTAL SALMON

INSIDE: PG&E'S NEW LOOK

Why PG&E Trims Trees, And What You Can Do To Help

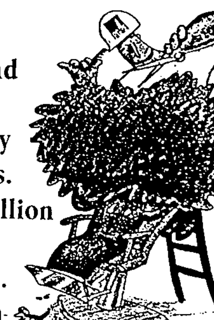


Illustration by Winthrop Prince

Tree pruning is important and necessary. In fact, state law requires utilities to regularly prune trees from high voltage lines. PG&E spends an average of $50 million a year pruning trees, and has increased the budget for the future.

Take a moment to look at the overhead lines in your neighborhood. There are three lines to recognize—the primary or high-voltage lines, the secondary or low-

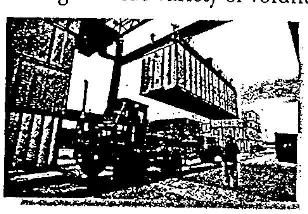
(continued on back page, col. 2)

PG&E Plays a Role In California's Economic Vitality

PG&E IS NOT ONLY THE GAS AND ELECTRIC COMPANY. WE'RE PART OF THE LOCAL ECONOMY IN EACH COMMUNITY WE SERVE.

To help make California a more attractive place to live and work, PG&E has created partnerships with other businesses, non-profit groups and community and government leaders through its Community Economic Vitality Initiatives.

In addition, PG&E employees have made contributions through a wide variety of volunteer and civic activities, such as



being members of local economic development groups and chambers of commerce and by serving on planning commissions.

The company's Community Economic Vitality Initiatives are a commitment to ensuring California's communities are competitive in today's global economy. They are:

SMALL BUSINESS DEVELOPMENT AND INCUBATORS

Business incubators are facilities where new and growing businesses operate under one roof, with affordable rents, flexible leases, shared services and equipment and access to professional management training and assistance. PG&E has helped to develop 20 business incubators which have created 1,100 jobs in northern and central California.

STRATEGIC COMMUNITY ECONOMIC PLANNING

PG&E has provided funding and leadership for organizations that are working to retain and attract businesses, generate jobs and promote strategic economic planning. These include the Tri-Valley Business Council, Joint Venture: Silicon Valley Network, the Bay Area Economic Forum and the Economic Vitality Corp. of San Luis Obispo County.

MILITARY BASE CONVERSION AND REUSE

A base conversion effort is occurring at the Alameda Naval Air Station, where PG&E recently approved a grant for the Alameda Center for Environmental Technology (ACET) business incubator. It will be home to 25 small businesses that will take the information from environmental research facilities around the country and translate that knowledge into products.

PG&E also contributed a grant to CALSTART, an alternative energy incubator at Alameda with (so far) eight businesses that are manufacturing parts for electric vehicles.

BUSINESS AND COMMUNITY CLIMATE IMPROVEMENT

By working with local governments and other agencies, PG&E seeks ways to create business-friendly climates in the communities we serve. For example, PG&E co-sponsored a conference in northern California for local government and business to simplify the often lengthy permitting process for new businesses.

PG&E thinks these initiatives are a win-win proposition: stronger communities and markets mean a stronger PG&E. For more information about our Community Economic Vitality Initiatives, call the community relations department at (415) 973-7389.

DEC. 25, 1996 SUPPLEMENT
ON LOCAL NEWS IN ZHB

Alameda Times-Star

Alameda

SPECIAL ADVERTISING FE

Alameda 'Hatchery' incubates high-tech

In the right environment, breakthroughs can happen. That's the goal of Calstart, which is operating a business incubator for advanced transportation technologies in the former aircraft Hangar 20 at Alameda's Naval Air Station.

A future benefit? Alameda would become a center for the advanced transportation industry, with more "clean air" vehicle companies and component suppliers setting up their facilities here.

The result could be hundreds of high-tech jobs and millions of dollars moving through the local economy.

This new venture is the first civilian reuse of former Navy facilities and equipment at the historic base, and the first transportation technologies business incubator in Northern California.

It's called Project Hatchery Alameda because the goal is to help the fledgling high technology companies survive until they're ready to fly alone into the marketplace.

Project Hatchery Alameda is a magnet for economic redevelopment of the city and provides an international focus on Alameda as a showcase for advanced transportation technologies.

To date, Project Hatchery Alameda companies have created more than 60 jobs in the city in the first 10 months of operation.

Project Hatchery Alameda has created public awareness of the high-tech industry through a partnership with the city's Bureau of Electricity to demonstrate electric vehicles.

Vehicles from companies in Project Hatchery have made appearances at Alameda's Fourth of July parade, Art & Wine Festival, the Park Street Car Show and Fleet Week.

Calstart personnel are working with other companies to organize a job fair to help the West Alameda Business Association prosper.

"We want Alameda to become the prestige address for the 'clean air' technology companies that will make advances in the surface transportation business in the 21st Century," said John Huetter, director of Project Hatchery. For more information, contact Huetter at (510) 864-3006.

— Beth Jaffe

Clearwater lo

Environmental firm seeks more work on military bases

By Beth Jaffe
CORRESPONDENT

Some say it's all in the genes. Her grandfather worked for the Sierra Club for some 20 years and started the Alaska Conservation Foundation, the main funding source for grass-roots foundations in Alaska.

Today, young entrepreneur Juniper Neill is vice president of Clearwater Group Inc., a company formed by five partners with a single goal in mind: to protect health and the environment by providing value-driven, commonsense solutions to environmental problems.

Born and raised in Alaska to parents involved in fishing and the tourism industry, Neill relocated to California to attend Mills College in Oakland. She graduated in 1991 with a degree in international relations and environmental studies, and now lives in Alameda.

Neill said she has always had an urge to "help solve environmental problems in large and small communities."

Along with her partners — Marcus Niebanck, Adam Niebanck, Madeleine Fulford and Henry Hurkmans — Neill started Clearwater three years ago; it now boasts annual revenues of more than $1 million.

From three Western offices in Oakland, Eureka and Portland, Clearwater serves the needs of

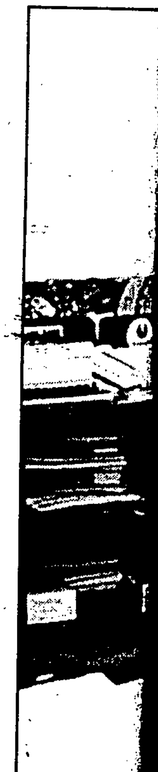


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Photo by Kathy Baker

Field trip pioneers

Students from Rising Star Montessori School recently became the first school group to ever take a field trip to the CALSTART electric car facility at Naval Air Station Alameda. First-graders Matthew O'Brien and Christina Ozuna and second-grader Cory Goodman checked out one of the small hatchbacks that go on batteries instead of gas. The CALSTART consortium was the first company to move to NAS as part of the base reuse effort.

East Bay Business Journal

VOL 1. No. 1 $1.00
WEEK OF OCTOBER 18 - 24, 1996

More firms for Alameda nest

By Lisa Stowell
STAFF WRITER

The nest of startup companies at the Calstart business hatchery in Alameda continues to fill as two fledgling companies prepare to move in Nov. 1.

CTJ Corp. and G&A Associates have signed lease agreements and hope to act as yet another success story operating out of the former Naval Air Station.

"They are further proof that something can be done down here besides shutting the whole place down," said John Huetter, director of Calstart's Project Hatchery Alameda.

In fitting with Calstart's charter, both companies will create high-tech jobs while developing environmentally friendly, advanced transportation products or services.

In return, the new companies will be nurtured along with consulting services, affordable space outfitted with machinery, and networking opportunities with other startup businesses.

CTJ, a former defense contractor now operating out of Hayward, supported the Alameda base since 1982. Two years ago, the company employed 35 people to provide engineering support for aircraft systems. Only six employees remain today.

"Although we were an adversely affected business," said CTJ Director Gary Baggett, "we want to stress the fact that we capitalized on our overseas contacts to survive the base closure."

Currently under contract with the Coast Guard in Oakland, Baggett said CTJ will continue to dabble in government contracts while at the hatchery, but with plans to focus on other Calstart participants.

G&A Associates, a company of three partners, will also move into Alameda's Hangar 20 at the first of the month.

"There's a real synergy that we believe will come about from relocating to the hangar," said company President Gary Noland.

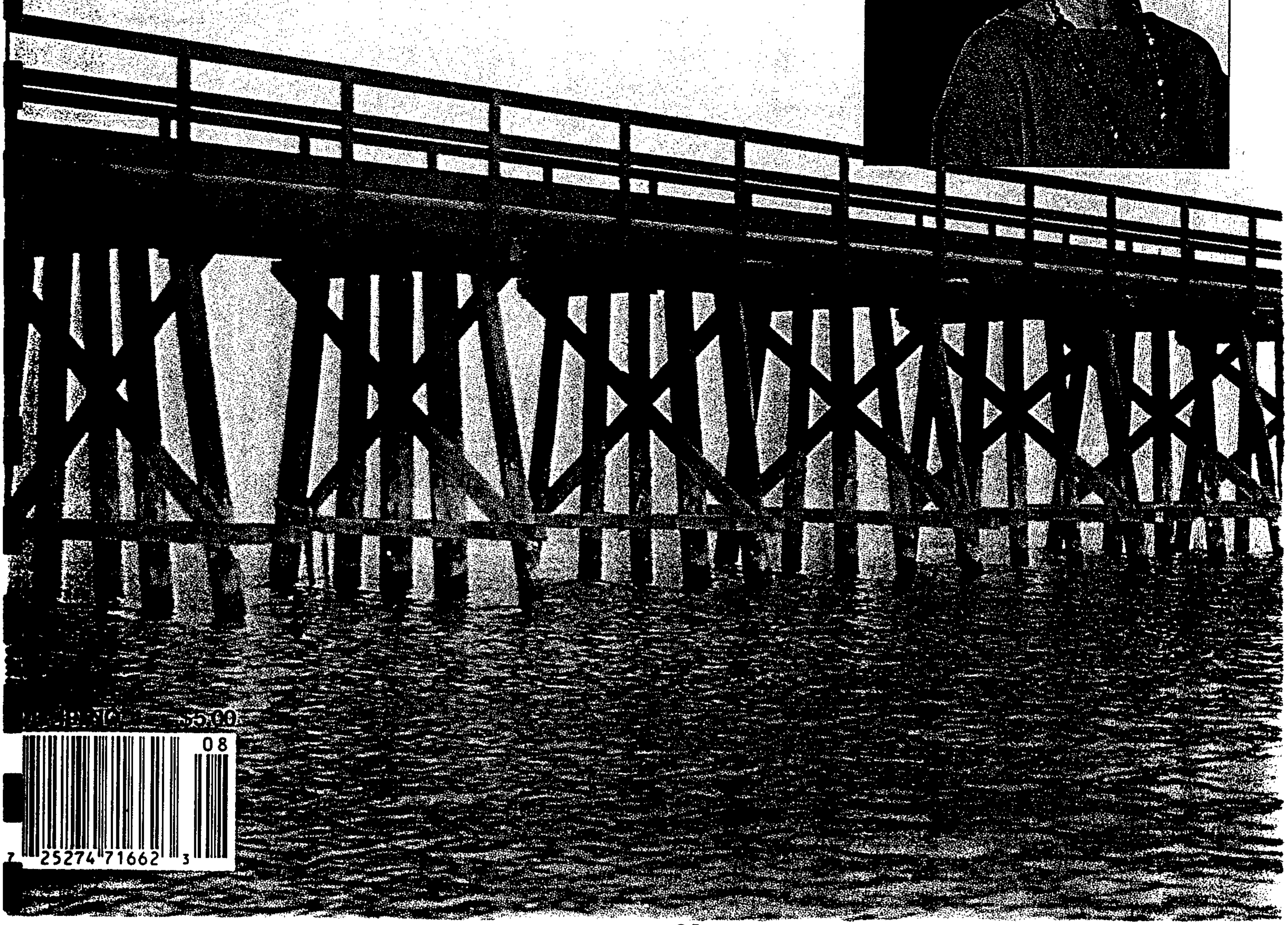
In the business of producing, storing, transporting and using hydrogen, G&A will work toward developing a hybrid engine -- an internal combustion engine and fuel cell -- that's only by-product is water.

in business®

CREATING SUSTAINABLE ENTERPRISES & COMMUNITIES

Recycling A Train Trestle

Paula and Gary Evershed launched a furniture company to make sure that a 90-year-old redwood trestle across the Great Salt Lake didn't wind up in a landfill.



FINANCING OPTIONS

When EBC creates new programs, it makes sure not to depend on continuous support from the surrounding public and private funding sources. "In order to raise capital for our Green Industry Commercial Loan Fund, we first obtained seed money from private companies, and from San Jose," Robbins notes. "The result is an independent fund that lends an average of $50,000 to a cluster member at the same interest rate as banks." So far, only a few of the companies in the cluster that received such loans have had minor repayment difficulties.

The Environmental Capital Network has proven to be another good source for funds. The Ann Arbor, Michigan organization connects small companies to investors and arranges conferences where entrepreneurs present their business ideas in an allotted time frame of three minutes each. "A business cluster with a specific focus is very attractive to investors, compared to a single start-up company," explains Robbins. "Some large corporations and banks are especially interested in doing a so-called strategic investment, by offering capital in exchange for a prototype of the new product, or simply by owning shares of the small company." The sums invested vary from $.25 million to $1 million per company.

EBC start-ups also may form strategic partnerships with larger corporations, as happened with one cluster company and a major manufacturer in the electronics industry. The small company was financed, and in return developed an environmental product that the large corporation needed. The corporation was provided with a certain amount of the product, and then the partnership ended. Similar partnerships have been very successful. "The challenge is to find the right person in the large corporation — somebody who sees the potential and makes the decision," Robbins says. Another creative way of financing the start-ups is to offer large corporations 10 percent of their profit each year, in exchange for a yearly contribution of capital.

CLUSTER MODEL

Companies in the Environmental Business Cluster are often run by only two or three people. Many of them are technically skilled, but lack business know-how. Some were fired due to downsizing at a previous job, and others wanted to switch careers. When the businesses are ready to "graduate," they have generally grown to employ 10 to 20 people. "The growth rate after graduation is exponential, although uneven," says Robbins. "A few companies become very big in a couple of years, while the majority have a more modest growth rate of less than 20 percent a year."

By the end of 1997, there are projected to be five environmental business clusters with 125 total companies operating in California.

Robbins has also started business clusters for communication and software start-ups. His objective is to start four or five clusters within all three sectors. The idea is that a high concentration of green businesses in a region leads to synergetic effects, just like Silicon Valley does for the computer industry. By the end of 1997, he hopes that five environmental business clusters with 125 total companies will be operating in California.

The cluster model also has successfully been used in converting military bases in the Bay Area to civil use. As a number of the bases are located in natural habitat areas, attention is being paid to ecological concerns during the conversion, and environmental companies and organizations have been participating.

One example is Project Hatchery Alameda, which is a part of CalStart, a comprehensive joint venture in the transportation industry. Sixteen small companies occupy the cluster located at the former Naval Air Station, Alameda. They develop technology for hybrid and electric cars, and other advanced transportation technology that aims to reduce air pollution. One company converts conventional cars to electric cars, and sells, rents and repairs electric cars. Another firm, Zap Racing, recently graduated from the cluster. It makes electric bicycles and presently employs more than 40 people. The cluster also aims at reaching fired personnel from the base closure, and currently employs around 60 people that previously worked at the base.

Photo by G. Hahn

John Huetter, project director of Project Hatchery Alameda, demonstrates an electric vehicle from Norway that will be used to shuttle commuters to and from mass transit stations.

John Huetter, project director, explains that the cluster model has become popular in California since the economic recession that started after the end of the cold war. "California lived long and well on a strong defense industry," he says. "With today's military disarmament, people have had to look for new areas of business and employment. The business cluster model has been shown to promote new, innovative small businesses." □

Gunnela Hahn recently completed a study on small, environmental companies in California and the Bay Area for the Swedish Office of Science and Technology.

A Journal 27 MAY 1997

Runway laboratory

The CALSTART electric car consortium took full advantage of the amenities at its new home at Alameda Point recently. In their search for a better way to test a vehicle's aerodynamics, engineers from CALSTART tenant Altamont Technologies Incorporated turned part of the old base's runway into a racetrack to test a formula race car (above) as well as electric cars (left).

— Photos by Kathy Baker

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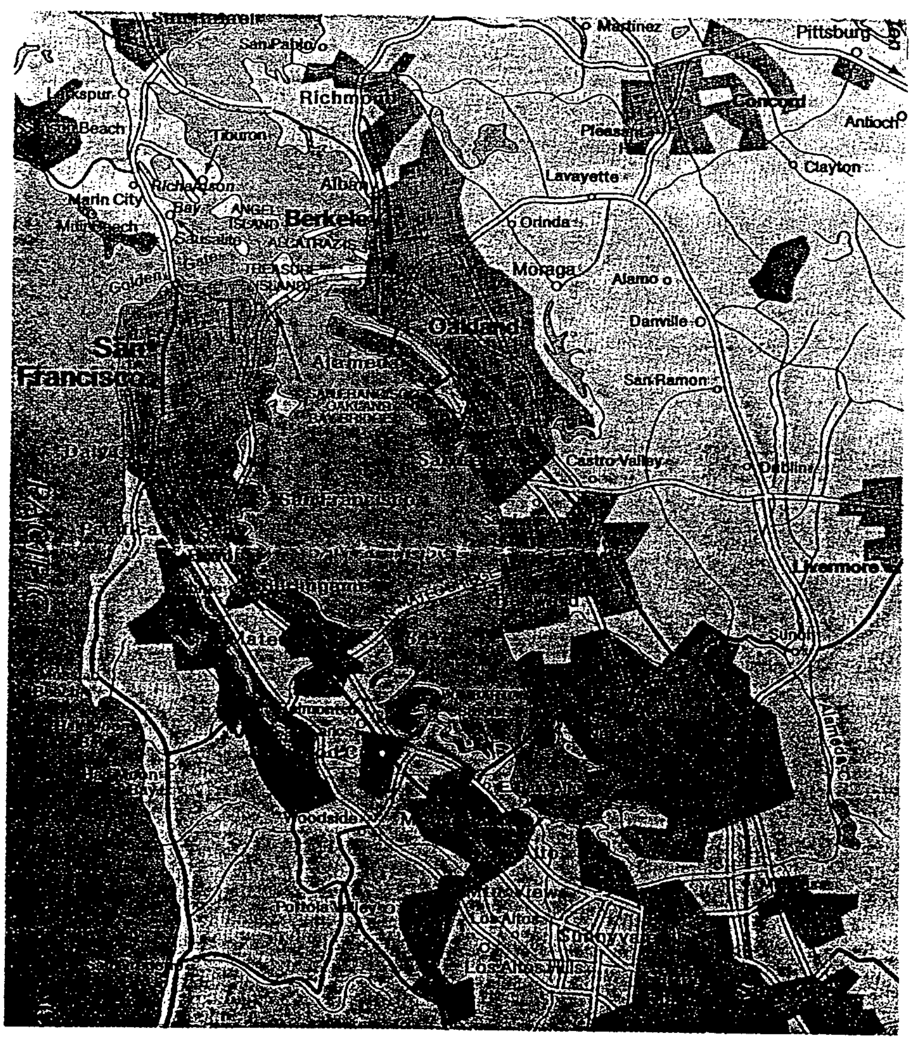
UTLANDS RAPPORT

I de gröna småföretagens värld
– en djupdykning i Kalifornien



Civilekonom Gunnela Hahn i samarbete med det teknisk-vetenskapliga attachékontoret i Los Angeles

som har den läggningen får här en chans. Först får de beskriva sin affärsidé. Därefter görs ett antal affärskonsulter steg för steg en bedömning av företagets möjligheter, en marknadsundersökning och slutligen en affärsplan. Endast de företag med riktigt goda förutsättningar att lyckas är kvar hela vägen. Ett tjugotal företag medverkar i projektet.

När affärsplanen har godkänts hjälper konsulterna till med att skaffa kapital och goda hyresvillkor. Allt sker på affärsmässiga villkor; företagarna får inga bidrag eller andra finansiella förmåner, utan ska stå på egna ben precis som sina konkurrenter. Skillnaden består i den professionella rådgivning som erbjuds kostnadsfritt. Workers to Business Owners erbjuder även utbildning, både i klassrum och individuell, samt mentorskap.

Under startperioden är företagen i ungefär ett år samlade i en så kallad *incubator* (kuvös), där de får kontinuerlig assistans. Platsen är en nedlagd flygbas i East Bay. Därefter följs företagen upp till dess att tre år har gått, då den mest kritiska perioden bedöms vara över. Projektet betalas av försvarsdepartementet och satsningen uppgår till totalt fyra miljoner kronor. En del av företagen kan räknas till miljösektorn, t ex ett som återanvänder virket i de byggnader på baserna som ska rivas. I Kalifornien bygger man ofta hela stommen i trä, vilket ger stora mängder återanvändbart virke.

⇒ *Paul Ammon, fax +1 (510) 864 31 54*

Project Hatchery Alameda

Project Hatchery Alameda är ett företagskluster inom det omfattande projektet CALSTART, som sträcker sig över hela Kalifornien. Sedan 1992 har CALSTART vuxit till att i dagsläget omfatta 185 större och mindre företag och organisationer, som är sysselsatta med att forska kring och utveckla ny, avancerad teknik inom transportsektorn. När deras prototyper har börjat tillverkas i större skala 1999, beräknas 40 av företagen sysselsätta nära 12 000 personer. Främst utvecklar man hybridbilar, dvs bilar som drivs av en kombination av t ex el och fossilgas eller el och bensin, men även moderna transportsystem finns på programmet.

Finansieringen av det femtiotal program som ingår i CALSTART kommer från privata och offentliga medel och omfattar mer än 700 miljoner kronor. Därtill kommer betydande privata investeringar i projekten. Idag rör det sig om fyra miljarder kronor och år 1999 beräknas investeringarna ha ökat till över tolv miljarder kronor.

Project Hatchery Alameda är ett av två företagskluster inom CALSTART, och huserar på en nyligen nedlagd flygbas i Bay Area. Det andra klustret finns i Burbank, Los Angeles.

Project Hatchery Alameda drivs på liknande sätt som *Environmental*

Business Cluster i San Jose (se nedan). Det innefattar ett dussin småföretag som utvecklar teknik för hybrid- och elbilar. Företagen får lägre omkostnader tack vare att de delar viss kontorsutrustning och har en förmånlig hyra. De har även tillgång till verkstäder, avancerade verktyg och instrument. En vanlig storlek på företagen i klustret är 3–4 personer, men företag som tillverkar prototyper har upp till tolv anställda. Klustret är självförsörjande genom att den hyresavgift som företagen betalar täcker samtliga driftskostnader.

Project Hatchery Alameda syftar även till att fånga upp personal som friställs i samband med nedläggningen av flygbasen, och sysselsätter i dagsläget ett sextiotal personer som tidigare arbetade på flygbasen. Ett företag sysslar med att konvertera konventionella bilar till elbilar, samt säljer, hyr ut och lagar elbilar. Ytterligare ett företag, som just har lämnat klustret, tillverkar elektriska cyklar och har i dagsläget drygt 40 anställda.

John Huetter är koordinator för Project Hatchery. Han förklarar att "incubators" eller kluster är en relativt ung form av företagande i Kalifornien. Formen har blivit populär efter den ekonomiska tillbakagång som startade efter det kalla krigets slut. Kalifornien levde länge gott på den starka försvarsindustrin. Med dagens militära nedrustning har man tvingats se sig om efter nya områden för sysselsättning och företagande, och värnar om nya, innovativa småföretag.

⇒ *John Huetter, fax +1 (510) 864 30 10*

Environmental Business Cluster (EBC)

Området kring San Jose har det välkända smeknamnet Silicon Valley, eftersom datorfirmorna fullständigt dominerar det ekonomiska livet där. En följd av detta är att dricksvattnet har blivit kraftigt förorenat av lösningsmedel som använts i tillverkningsprocessen för kretskort. Området har dessutom problem med bostadsbrist och trafikstockningar.

För att stärka regionens konkurrenskraft har olika grupper startat ett gemensamt nätverk, *Joint Venture: Silicon Valley Network*. Målet är att skapa en ekologiskt hållbar ekonomi och välbetalda arbeten. Tyngdpunkten ligger på miljörelaterad teknik och tjänster. I nätverket möts industri, myndigheter, forskare och miljögrupper, som lär sig att gemensamt hitta lösningar på och förebygga problem och eventuella konflikter mellan olika intressen. Nätverket ordnar även seminarier m m för att utbilda medlemmar och allmänheten i miljöfrågor.

I nätverket läggs stor vikt vid att främja ny teknik och nystartade företag med goda affärsidéer. Därför har en småföretagsgrupp startats, *the Environmental Business Cluster* (EBC), där lovande företag i miljösektorn får

Business Journal

CALSTART's "Project Hatchery" helps new advanced transportation companies find market

This is the first of a two-part series on CALSTART

Photo by Kathy Baker

Pictured are PIVCO cars getting a final polish after a routine maintenance check. These cars are part of the BART Station Car Program managed by Green Motorworks. Participants in the program use the PIVCO cars and BART to get to and from work/home.

In 1994, faced with the closure of Naval Air Station Alameda, Congressman Ronald V. Dellums (D-Alameda/Oakland) teamed up with CALSTART, a statewide non-profit consortium, to develop a plan to re-employ base workers and improve air quality through development and deployment of "clean air" advanced technologies. Dellums and CALSTART agreed to develop Project Hatchery Alameda (PHA) as a business incubator, specified by the Clinton administration to be a model of military base reuse.

The "Hatchery," as the business incubator is known, is located in Hangar 20 at the base, which was formerly used to house aircraft from World War II through Desert Storm. The Hatchery lease was signed in 1995, and today is 95 percent occupied by 16 companies. CALSTART is looking to expand into another facility on the base.

"The reuse of this military base for the development of advanced transportation technologies shows what can be done," said Michael J. Gage, president and CEO of CALSTART. "The early support of small and start-up companies makes all the difference — for the government, for individual companies, for improved air quality and for economic opportunity."

According to John Huetter, CALSTART's director of Project Hatchery Alameda, there is a waiting list of qualified advanced technology start-up companies that want to move in.

"The word has spread that we support innovative alternative transportation projects in a variety of substantive ways. I get calls every day," Huetter said.

In addition to providing space for potential new tenants, an expanded Hatchery would also allow existing companies to extend their research and development work, including ongoing work with prototypes of electric vehicles and hybrid-electric vehicles.

In April 1997, the Navy will officially cease operation at the base, and the Naval Air Station will be retired. After that, the Hatchery will be known as Alameda Point, a name suggesting more bucolic surroundings than old aircraft hangars, but tenants seem to enjoy the location. "Our companies enjoy the proximity to the city while not having the hassles of city commuting," Huetter said.

A service implemented by PHA's first birthday last November is the "Hatchery Associates," a group of law, accounting, business management and finance specialists that provide assistance to Hatchery companies. "As (tenant) companies move through product development to production, we saw a need for these service," Huetter said. Professionals willing to donate their time were recruited and additional associates are being regularly developed in specialty fields to support PHA tenants.

The Alameda hatchery is seeing increased activity in 1997, which will include participating in an international electric vehicle exposition later this year.

"This industry is on the move," said Gage, "there's no more waiting for the technology to be developed. It's here, it's today, it's the future and we will keep leading the way for this industry."

CALSTART focuses its efforts primarily in California, though it has been expanding to other states and internationally as well.

"This technology is limited only by imagination," Gage said, "and fortunately for this nascent industry, imaginations are on fire!"

More information about CALSTART and its participants can be obtained by a visit to CALSTART's website: www.calstart.org

(The second part of this article will appear in the April 15 Business Journal and focus on the 16 Hatchery companies.)

Project Hatchery Alameda Directory

Company Name	Description
Alameda Center for Environmental Technologies	Developing an incubator for environmentally related companies
Altamont Technologies, Inc.	Development of fuel-efficient, lightweight, monocoque composite transport modules
Amerigon, Inc.	Supplies advanced automotive electronics & electric vehicle components
Clean Air Products Technology	Develop and fabricate process clean-up and recycling equipment
CTJ Corporation Technology	Transfer, export, and manufacturing ventures to the Pacific Rim.
Datronics Design,	Develop and prototype unique electric "Power-lift Wheelchair"
EBCRC-Workers to Business Owners Project	Helping former base workers develop their own businesses
Forem Metal Manufacturing	Truck body modifications to increase payload and access
Franklin Environmental Environmental	Products for wastewater, remediation, and oil spill clean-ups
Green Motorworks	Conversions to electric vehicles. Electric vehicle sales, leases, and service
HORNET Foundation	Preserve and operate the xUSS Hornet as a floating museum and base re-use facility
Jefferson Programmed Power	Developing and producing high power DC controllers for electric vehicles.
Kaylor Energy Products	Designers & manufacturers of hybrid and electric conversion kits and vehicles
Procyon Power Systems	Development of a hybrid vehicle engine based on a reactor/fuel cell
Puglia Engineering	Transportation infrastructure and ship repair/rehabilitation
Zebra Motors	Development and manufacture of high performance electric sports cars.

PG&E Week

A Publication for Pacific Gas and Electric Company Employees and Retirees

December 16, 1996

East Bay Division: Meeting the challenges of change

Military and industry make way for high tech.

OUR THIRD IN A SERIES OF ARTICLES profiling PG&E's 18 divisions focuses on East Bay Division. This bayside, mostly urban division covers Alameda County from Oakland north, and western Contra Costa County from El Cerrito to Port Costa on the Carquinez Strait.

DIVISION PROFILES

East Bay Division is one of PG&E's most urban, serving a region that includes Oakland, Richmond, Berkeley and a dozen smaller cities. Its residential customers span a diversity of cultures and socio-economic strata; its business customers range from steel mills and oil refineries to modern, rapidly expanding high-technology firms. Large public institutions like Kaiser Permanente hospitals, a huge U.S Postal Service mail-sorting facility and the University of California's world-famous Berkeley campus are also in the mix.

East Bay Division has some challenges to grapple with—pending closure of five military facilities, partial loss of big customers like Bay Area Rapid Transit and the Oakland International Airport and some of the oldest circuits in the company's service territory.

But it also has many successes to cheer, including a massive, on-time and under-budget project to underground electric service in the Oakland hills "fire zone," inner-city business "incubators" to spur economic activity, a positive image among local government bodies and many long-time employees who say they wouldn't work anywhere else.

—continued on page 2

End of Cold War jump-starts hot cars

In a hangar at the Alameda Naval Air Station, Bob Orbeta, East Bay Division base re-use project manager, sits behind the wheel of a Zebra Motors electric car, while strategic planner Paul Alliegro and Calstart's Project Hatchery Alameda director John Huetter discuss the fine points.

PG&E supports incubators to stimulate local economies.

East Bay Division is home to two of more than 20 business "incubators" PG&E has helped establish throughout its service territory. The incubators are intended to boost economic activity in local communities by bringing several small businesses together to share equipment, office and production space, and providing them with legal, financial and marketing advice.

At the Alameda Naval Air Station, PG&E has contributed $25,000 to Calstart, a non-profit consortium dedicated to developing a clean-air vehicle industry in California, and is offering technical expertise to businesses involved in the project.

"The incubator will help attract other businesses to the area after the base closes," says base re-use project manager and Emeryville and Alameda area manager **Bob Orbeta**. In

—continued on page 4

Incubators

—from page 1

addition, says business incubation project manager **Ila Homsher**, the economic impact of the incubator will extend beyond the base by creating jobs and income for the region.

The Navy's departure from ANAS is scheduled to be complete next April. Calstart's incubator opened last January in a hangar on the 1,842-acre base, and now houses a dozen businesses employing about 60 people.

Zebra Motors uses its space to develop prototype electric vehicles. Zebra president Larry Stadtner says his company's battery-powered cars produce only one-tenth the pollution gasoline-powered cars emit, including the pollution generated to produce the electricity needed to recharge the cars.

PG&E provides more than just funding for incubator startups, says Homsher, as company employees advise incubator managers and tenants on utility needs, refer them to other experts and community leaders, and serve on advisory boards.

Another incubator in the East Bay Division opened this fall in downtown Oakland, housing 13 small communications technology companies that employ nearly 40 people.

Supporting incubators and assisting in military base conversion are both components of the company's Community Economic Vitality Initiatives, launched in 1994 to strengthen California's economy and PG&E customer loyalty, says CEVI team lead **Amy Garant**. Other components include helping communities with strategic planning and affordable housing.

Several more incubators are being planned in the East Bay. PG&E has helped fund development of an environmental technologies incubator at ANAS that is projected to house up to 25 businesses employing 200 people when it opens late next year. An incubator for bio-science firms is being planned for Hercules, a bedroom community north of Richmond, and preliminary discussions have been held for incubators in the city of Richmond, including one at the Point Molate Naval Fuel Depot.

—*Eric Jansen*

New Businesses Find a Safe Place to Grow

'Incubators' back groups of startups

By David Tong
Chronicle Staff Writer

Larry Spadtner's high hopes of producing an affordable all-electric sports car enters into a new stage early next year when his company starts manufacturing the first batch.

For the past six to eight months, Spadtner and his colleagues at Zebra Motors have been working at a business incubator at Hangar 20 of the Alameda Naval Air Station, putting the final touches on the car, which will carry a sticker price of $19,700.

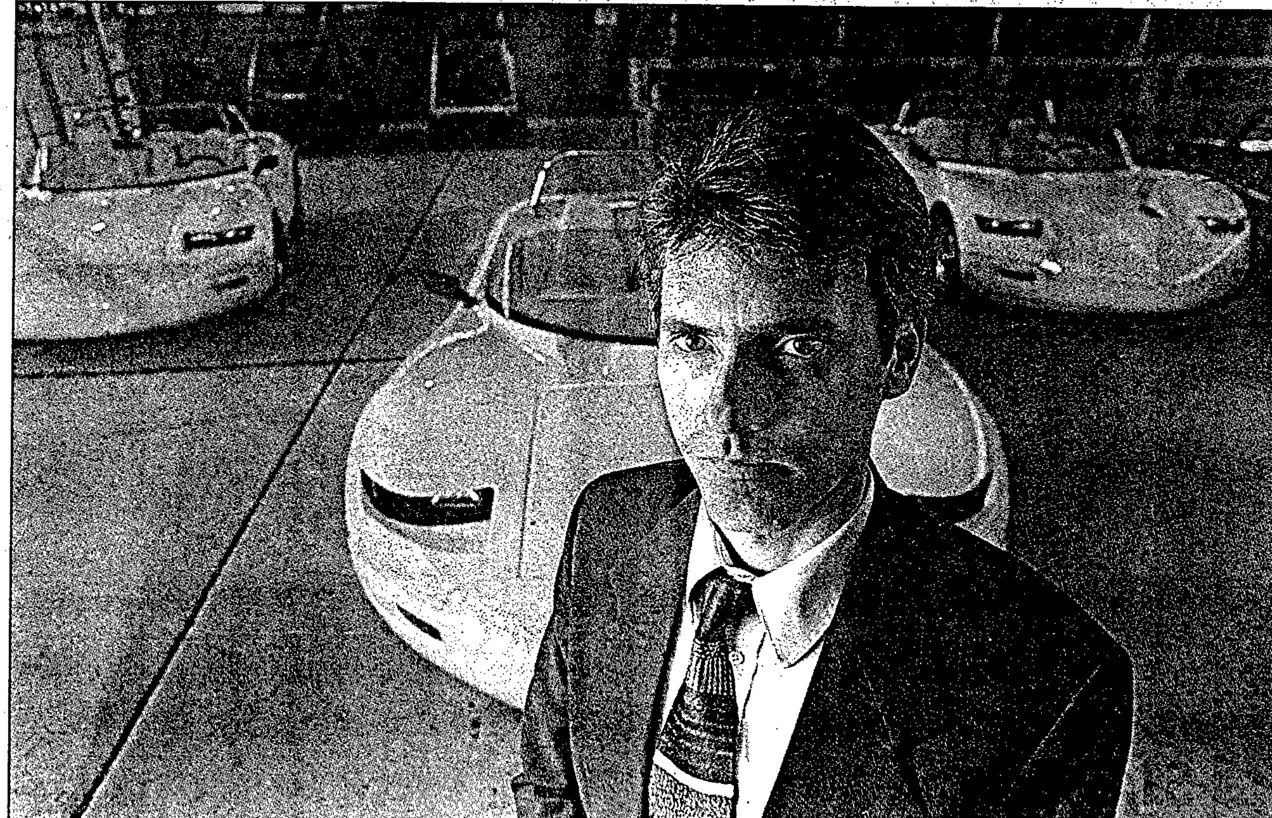
Most incubators are nonprofit organizations dedicated to getting new businesses off the ground. The idea is to gather a group of entrepreneurs in one facility to exchange ideas and share overhead costs.

For a subsidized monthly rent, the entrepreneur receives office space and shares office equipment, conference rooms and secretarial services. The incubator also provides legal, marketing and professional consulting help to the entrepreneurs. Incubators usually appoint an executive director who runs daily operations.

Spadtner said the incubator at the CalStart Project Hatchery in Alameda has provided invaluable contacts with other companies involved in clean-air technology. "It's the synergy with other companies related to our electric vehicle," said Spadtner, who moved his company from Novato to Alameda. "Our business has been allowed to grow. Now the egg is breaking, and our babies are coming out."

He isn't alone. Business incubators have taken off in California in recent years, providing business startups with a much-better-than-average chance of success.

In the past five years, the number of incubators in the state has jumped from 12 five years ago to



Larry Spadtner, president of Zebra Motors, is planning to produce his first all-electric sports cars next year after working for six months at an incubator at Alameda Naval Air Station

PHOTOS BY TIM KAO/THE CHRONICLE

'It's the synergy with other companies related to our electric vehicle. Our business has been allowed to grow. Now the egg is breaking, and our babies are coming out.'

— LARRY SPADTNER, of Zebra Motors

other companies.

According to Jim Robbins, director of the Environmental Business Cluster, a San Jose incubator, 80 percent of incubator startups remain in business after five years of operation compared with only 30 percent for startups that work independently.

Traditionally, business incubators were set up to assist business startups in inner cities.

Today, business incubators are nurturing businesses in fast-

the San Jose-based Software Business Cluster, which has helped 12 companies that have created 500 jobs.

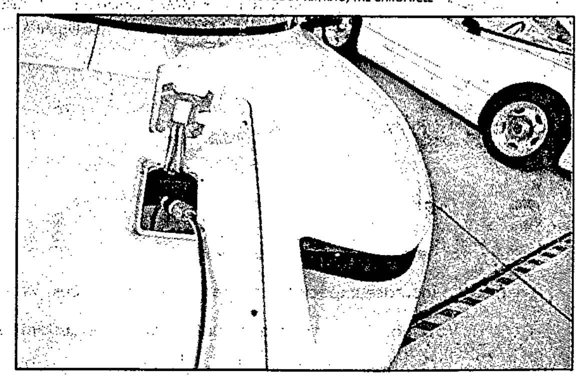
Business incubators can take different forms. Gordon Campbell heads Tech Farm, a Sunnyvale for-profit incubator that has worked with 16 startup companies, the most notable of which is 3Dfx Interactive, a San Jose maker of chips that enhances the images of 3-D video games for arcades and personal computers.

also receives heavily discounted founder's shares in the participating companies.

Today, 3Dfx has a market capitalization of $250 million and a workforce of over 100.

By contrast, the CalStart Project Hatchery is a private, nonprofit incubator that relies only on the lease rates it charges tenants to cover operating costs.

For monthly rents of 75 cents per square foot for office space and 50 cents for shop space, ten-



Zebra Motors' prototype sports car takes six hours to recharge

expanded from five startups to 10 and has space for 10 more. It has a

ing resource center to help small business startups qualify for fi-

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

NAVAL AIR STATION ALAMEDA CLUSTER PLANNING FINAL REPORT

CALSTART

Naval Air Station Alameda Cluster Planning

MDA 972-95-2-0011

DARPA

Submitted by:

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Alameda, CA 94501
510-864-3000

Naval Air Station Alameda Cluster Planning
FINAL REPORT
(DARPA RA94 Mod 3)

1. **Introduction** CALSTART was tasked and funded to plan for an advanced transportation business cluster at NAS Alameda. The specific objectives delineated for CALSTART in this program were:
   1) Work with other organizations to develop a cluster of advanced transportation (AT) activities at the Alameda Naval Air Station.
   2) Try to recruit other AT firms to locate at the NAS.
   3) Encourage Project Hatchery Alameda (PHA) firms to grow and expand into their own facility at NAS Alameda.

Specific activities identified and levels of performance achieved are covered in the next section. Overall, CALSTART has established the relationships and identified the processes necessary to continue the work of transforming former NAS Alameda into a center for the AT industry. Two of the companies that have transitioned out of CALSTART's Project Hatchery Alameda (PHA) have been located in their own facilities at the former NAS. Two more PHA companies are in negotiation to make the move into other buildings within the next 3-4 months.

2. **Accomplishments** Specific items accomplished under this program are recited below in response to the task statement. They include:

   1) Assess and identify viable office and industrial facilities at the NAS.All industrial and commercial buildings, except for food services, were surveyed. Specific buildings were identified for vehicle production or assembly. Controlled environment facilities were identified and pre-qualified for composite manufacture and final assembly, storage battery production and refurbishment, and painting. These facilities represent a unique asset of the former NAS and should be used to their best purpose. Former aircraft hangars have been matched to the manufacturing space requirements of individual AT companies. As examples, Hangars 39 or 40 are a near exact match to the footprint of the modular manufacturing plant designed for PIVCO CitiBee production up to 5000 units/year. Hangar 23 has been optioned by Zebra Motors, currently a PHA resident. They can produce up to 4000 units/year of their all electric roadster or utility van.

   2) Develop marketing materials and purchase necessary equipment Marketing packages presenting the availability and advantages of locating at the former NAS were developed for specific presentations to PIVCO senior management, Corbin Industries owners, and the founder of Altamont Technologies. An NAS Alameda facilities re-use presentation was developed by CALSTART. Equipment to supplement those items made surplus by the Navy was acquired.

3) Develop cluster outreach program
   CALSTART staff worked with the West Alameda Business Association and City of Alameda agencies such as the Bureau of Electricity and the Economic Development Dept. to attract and refer potential AT and related support companies to the former NAS. Links to the community were established in a series of briefings and presentations, describing the activity underway and inviting continued participation. The network of agencies has resulted in a cooperative referral and support group that is working toward the mutual goal of an AT technologies and service hub. CALSTART organized and co-sponsored the first Electric Vehicle Exposition at NAS Alameda to bring public attention to the focus of base re-use on advanced transportation. This event received regional pre-publicity and extensive coverage in major media outlets while attracting five OEM companies, as many small manufacturers, and approximately 2500 visitors to displays and demonstrations of CFVs.

4) Identify and mobilize additional regional resources
   The following regional resources or agencies have been mobilized and are active in support of the Advanced Transportation cluster development:
   - East Bay Conversion and Reinvestment Commission
   - Economic Development Alliance for Business
   - U.S. Dept. of Energy Regional Operations Office
   - Greater Oakland International Trade Center
   - Alameda Re-use and Redevelopment Authority
   - City of Alameda Manager
   - Alameda Bureau of Electricity
   - Economic Development Department
   - Alameda Education, Technology & Business Consortium
   - Bay Area Defense Conversion Action Team
   - Mayor of Alameda Ralph Appezzato
   - University of California, Berkeley
   - Pacific Gas & Electric Co.
   - Lawrence Berkeley Laboratory
   - Other regional business incubators

   The CALSTART effort has also gained visibility at the level of the Bay Area Economic Forum and initial approach has been made to participate in the Bay Area Coalition for a Sustainable Economy, aimed at ensuring long-term high quality of life based on clean air and clean water technologies in the Bay Area.

5) Create strategic partnerships
While the relationships established with the groups and companies noted in Item (4) speaks to the partnering toward the goal of an AT cluster at Alameda, two strategic partnerships have emerged that appear key to the eventual success of this mission. CALSTART's partnering with the EBCRC has resulted in a sustained and cooperative recruitment and support for companies that fit the technology profile, especially where there is an intersect with economic revitalization of the region. The partnership with Alameda's municipal utility, the Bureau of Electricity, has resulted in co-sponsorship of the Alameda EV Exposition whose primary function is to focus on the former NAS as the premier AT industry location in the region. In concert with this effort, CALSTART was invited to help write portions of the City's General Plan to designate Alameda as the EV Model City as a matter of public policy. The intent is to create both a user and business environment that is friendly to CFVs in all respects, including infrastructure.

6) Facilitate lease arrangements at NAS
CALSTART has provided support to FOREM Mfg., Zebra Motors, and Jefferson Programmed Power among other PHA companies in lease negotiations with the ARRA. Staff have consulted to other companies planning on relocating to the former NAS. We have agreed to identify and provide a timeline for expected PHA "graduates" to the ARRA to enable advance planning for facility use by the high tech companies. CALSTART and the ARRA agreed to formulate a plan for AT and related technology expansion at NAS under supervision of the City Manager. Joint City/Navy jurisdiction, among other factors, have restricted the capacity to streamline the leasing and facility occupancy process.

7) Integrate effort with other CALSTART information programs
NAS cluster planning is included as part of CALSTART briefings and presentations on our activity in the AT industry. In addition to an expected revenue source, development of the test track has been done to attract other AT users and developers to the base. This recently established capability in being incorporated in CALSTART Alameda brochures and made a part of the on-going marketing program. Corporate press releases have been crafted to emphasize the role of the company as a focus for re-development of NAS as a hub for AT firms.

3. <u>Deviations to Plan</u> As noted in Section 2, the specific activities have been accomplished or addressed. The requirements for a streamlined leasing and facility re-use process have been identified but are beyond the authority of CALSTART to implement. While it was anticipated that our experience as the first civilian lessee at NAS would create a template for future use, this has not been the case.

Also, despite significant and protracted efforts to forge strategic partnerships directly with major, established advanced technology and advanced transportation companies, no deals have been finalized between these players and start-ups at the NAS. We believe this can be an important part of validating this location as the regional AT hub and will continue to work toward such partnerships, including those featuring investment. We were successful in bringing one of our CALSTART PHA companies, Kummerow Corp., into a partnership with the Bureau of Electricity for technology use and distribution.

4. **Projections** Events that can affect project goals are not primarily technical. Problems in realizing NAS status as an AT hub are likely to be based in perceptions by the business community or slowness to react positively by existing agencies and institutions. The economic opportunity message has been broadcast by CALSTART. It needs to be carried by other stakeholders in the future. Alternatively, CALSTART could be funded to continue the work that it has been doing with the benefit of the valuable experience gained to date. Initially, ours was the only focused base re-use plan. Other plans for very mixed industrial and social re-use of the NAS may also dilute the impact of the AT center message.

5. **Financials** The project was accomplished within budget. The grant funding enabled this effort to happen. An industry focus for base re-use, for the City of Alameda, and for the East Bay region would not have happened without this support. This project created a distinct and unique identity, both with the agencies identified and the general public. There were no cost overruns.

6. **Conclusions** Funded effort on this project has been completed. Impact of the project has been to create an awareness that the former NAS Alameda is being re-established in a civilian role as a center for the AT industry. It appears that the first positive results of this effort will be in the form of transportation companies that are outgrowing the PHA incubator and being retained at base locations. CALSTART's facility has acted as a magnet for at least 20 firms to locate at the now closed base.

   Unless there is a funded extension of the CALSTART effort, the planning for an AT cluster must be done by the City as part of its EV Model City Plan. A parallel and likely scenario is the steady transition of start-ups through PHA to commercialization, given an operating environment that supports retention on-base.

   Reports on the evolution of NAS Alameda towards an AT technology hub are attached.

Alameda Ti

WEDNESDAY: Ju

Civilian goods shape up,

Base reuse starts with car frames

By Kathleen Kirkwood
STAFF WRITER

ALAMEDA — Electric car frames, products of the first civilian venture at Alameda Naval Air Station, are being shipped out this month for customers in Asia.

The lightweight aluminum frames are for the EV-4, a small car designed by Amerigon Inc.

The firm is part of CALSTART's hatchery of eight alternative vehicle companies at the Alameda base, due to close in April 1997.

Depending on production schedules, Amerigon will ship between 100 and 150 of the frames this year, said Dave Gallup, Amerigon director of operations.

The frames will not be sold domestically, at least for now, because the EV-4 is smaller, slower and more Spartan than the vehicles Americans generally buy. The car, which costs about $6,000, does not have a stereo system or sunroof — and can't go faster than 40 mph or long distances.

The Amerigon venture is the first product of CALSTART's hub at the base, which opened last fall in a vacant helicopter hangar.

CALSTART and city officials are hoping the production center will help lure a bigger electric car venture, PIVCO of Norway. The company is now shopping for a site in California to set up production lines for its Citi car, a small electric vehicle that would sell for between $10,000 and $15,000.

The Citi would closely resemble the two-seater CityBees that are now part of a commuter demonstration program that Sybase employees use between their Emeryville office and the Ashby BART station in Berkeley.

CALSTART and Alameda are trying to assemble as many "p
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plus by the Navy.

Navy Base Hangar to House Electric Car Assembly Line

The rededication of Hangar 20, a World War II vintage airplane and helicopter hangar at the Naval Air Station (NAS) Alameda, to a new state-of-the-art electric car chassis manufacturing facility should jump start the successful economic conversion of the base to new civilian economic uses.

"...an innovative utilization that starts constructive civilian economic use before the base is even closed."

The event was hosted by conversion officials from the Alameda Reuse and Redevelopment Authority (ARRA), the East Bay Conversion and Reinvestment Commission, and my district congressional office. The new-technology cars that will be produced at the site will help to reduce air pollution, meeting future California automobile exhaust emissions requirements. The siting of this facility at the NAS Alameda gives a competitive edge to the region in future technology developments and will aid the nation in maintaining a lead in this important economic sector.

Deputy Assistant Secretary of the Navy William J. Cassidy, Jr. presided over a Veterans' Day ceremony at which Navy commanders "turned over the key" to Hangar 20 to the heads of CALSTART and Amerigon, two organizational leaders in this technology field. This action launched the first civilian/commercial use of NAS Alameda base property — an innovative utilization that starts constructive civilian economic use before the base is even closed. Such interim leases to organizations that will create jobs for regional economic growth is a concept that community planners have promoted to accelerate the conversion of closing military bases. We are pleased that it is being utilized in the East Bay.

Secretary Cassidy was joined by officials from the Defense Department's Office of Economic Adjustment, the Department of Commerce's Economic Development Administration, and the Federal Transit Administration. These agencies are also aiding our community conversion effort with vigorous support.

CALSTART is a nonprofit consortium of labor unions, advanced transportation technology firms and agencies. Amerigon, Inc. is an electric car chassis manufacturer. Their interim lease with ARRA will allow them to establish a transportation "incubator" for the required new technologies. In addition, Amerigon will convert the 65,000 square foot hangar to an "agile" manufacturing facility for chassis construction. Three other high-tech transportation firms join the initial venture with potential for more to come. They will serve an already existing market for the prototype aluminum chassis and component parts.

President William J. Clinton joined me at the Alameda County Central Labor Council's Labor Day picnic and announced a $2.9 million matching grant to CALSTART for the manufacturing center. The grant is from both the Department of Defense and the Federal Transit Administration. The electric car assembly line will generate an initial 50 civilian jobs with the potential of several hundred more. This positive first step in the productive reuse of the air station should lure similar busineses to the area.

Hangar 20, commissioned in 1941 for Navy aircraft, sits at the hub of transportation history. Its rededication to civilian use signifies a historic link from this past to employing the newest transportation technology towards productive, environmentally sound, peacetime uses.

Key to the Future — New Jobs for A Closing Base

In a symbolic ceremony, the Commanding Officer of Naval Air Station Alameda turns over the key to Hangar 20 to CALSTART, launching the high-tech vehicle facility. Pictured, left to right, are Alameda Mayor Ralph Appezzato, CALSTART Vice-President John Boesel, Rep. Dellums, and Captain James Dodge, USN, NAS Alameda Commanding Officer.

Photo by: Cleo's Photography

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The new Electric Flash

City of ALAMEDA Bureau of ELECTRICITY

Volume 9 • Number 12 • December 1996

Alameda's on the Fast Track with Electric Vehicle Production

Imagine driving in a world with cleaner air, never stopping for gas, and never having to worry about an oil change. Well imagine no more, because that world is fast becoming a reality as Alameda becomes *the model city for electric vehicles!*

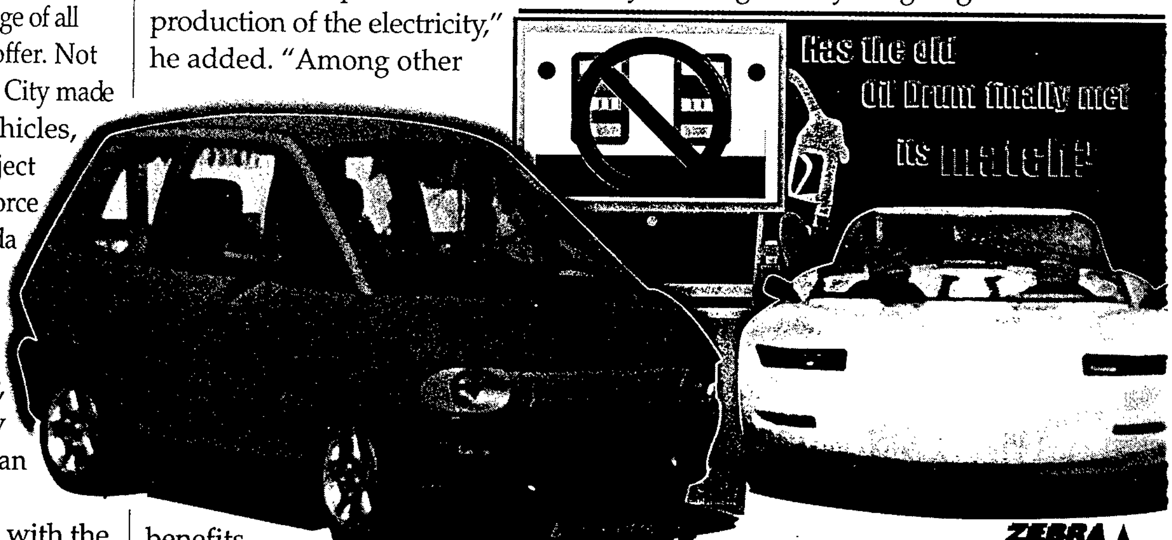
At a time when the electric vehicle industry is taking off, our City is in the best possible position to take advantage of all that electric vehicles have to offer. Not only have the Bureau and the City made a commitment to these new vehicles, but also CALSTART's Project Hatchery Alameda is in full force at the Naval Air Station - Alameda.

"CALSTART is a non-profit consortium developing advanced transportation technologies," said John Huetter, director of Project Hatchery Alameda. "Our goals are clean air and job development."

The Bureau's goal, along with the City's Electric Vehicle Task Force, is to encourage the research, development, production, sales, and service of electric vehicles, while at the same time helping to reemploy displaced defense industry workers — right here in Alameda.

Cleaner Air, Lower Costs

"Electric vehicles do not emit any pollution," said Jim Baak, the Bureau's Rate Analyst/Forecaster. "And, because two-thirds of our electricity here in Alameda is geothermal or hydroelectric there's also almost no pollution in the production of the electricity," he added. "Among other benefits, electric vehicles are very quiet, so they reduce traffic noise, and there are no oil or transmission fluids which can drip and contribute to urban runoff."



ZEBRA ▲

Owners of electric vehicles will enjoy other savings, too. According to Baak, operational costs of electric vehicles are only one-quarter those of internal combustion vehicles. It costs less than $1 in electricity to fully charge an electric vehicle!

Considering an internal combustion engine has 25,000 to 35,000 moving parts and electric vehicles only have one-tenth of that, the savings are substantial — and there's much less hassle. Additionally, lead acid batteries (on which many electric vehicles now run) are 98% recyclable.

Convenience is the key with electric vehicles. "With electric vehicles you can go into your garage and recharge and never go into a gas station again," said Baak. By the end of the year, the Bureau of Electricity plans to offer a discount service rate on electric vehicle charging to its customers.

The best part is that electric vehicle technology is being produced right here in Alameda — and that means more jobs and a brighter outlook for the economic health of the City and the redevelopment of the Naval Air Station (NAS).

► **ELECTRIC CARS** *continued on page 4*

► ***ELECTRIC CARS*** *continued from page 1*

Right now, 14 companies are part of CALSTART's consortium. Two, Zebra Motors, Inc. and Kaylor Energy Products actually manufacture electric vehicles at NAS.

Zebra is currently taking orders for its Model Z sports car, which will make its debut in mid 1997, and Kaylor specializes in turning existing vehicles into hybrid vehicles, so you can run them either on gasoline or electricity.

CALSTART also hopes to lure PIVCO, the Norwegian manufacturer of the smaller, more economical Citi Bee, to NAS in the near future, creating even more jobs.

Alameda, The Model City

In order to promote electric vehicles and the Electric Vehicle industry development NAS, the Electric Vehicle Task Force was formed. It includes representatives from the Bureau, CALSTART, the City, local business parks, and other interested parties. Their work has really caught on. Resolutions supporting an Electric Vehicle Model City Program have been passed by the Alameda City Council, the Public Utilities Board, the Economic Development Commission, the Alameda Chamber of Commerce, and the Base Reuse Advisory Group.

"We wanted to make sure the rest of the community was ready for electric vehicles, and that means making sure the infrastructure is in place to support them," said Baak, who chairs the Task Force

Included in the Task Force's plan is training for local Police and Fire personnel on electric vehicle emergencies, working with local schools to train people in the service and maintenance of electric vehicles, and establishing commercial charging stations.

"Alameda is the ideal place for electric vehicles because it is self-contained," said Baak. "The City is only about 12 square miles, and you can fulfill most of your needs around town. The mild climate and flat geography are also ideal for electric vehicles."

"Electric vehicles are intended to replace the commuter in-town vehicle," Baak adds. "It's not very efficient to jump in your sport utility vehicle to go to the store to pick up groceries or to go to the BART station or ferry terminal."

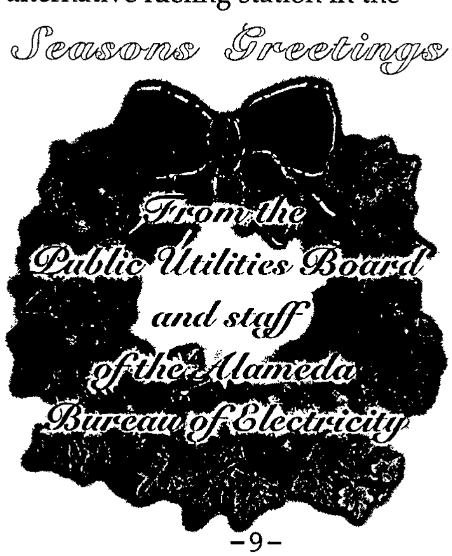
The Bureau currently uses three of their own electric vehicles and has a charging facility. The City's Building and Electrical Inspectors also use electric vehicles.

A Look Ahead

Beyond offering lower rates to electric vehicle users in the upcoming year, the Bureau and CALSTART have big plans for 1997. Alamedans can look forward to one of the largest electric vehicle expositions in California in September. To be staged at NAS, the expo will include models from every electric vehicle manufacturer, as well as electric vehicle races.

Alamedans may also get a chance to take an electric water taxi ride and rent electric vehicles to commute to work from ferry terminals. There is also a proposal for an alternative fueling station in the City which could supply methanol, compressed natural gas, propane, and quick charging for electric vehicles.

Alamedans can also look forward to a brighter future, with cleaner air and more jobs. "Our plan at CALSTART is to act as a catalyst for the reuse of NAS and the revitalization and reemployment of the City," said Huetter.



For More Information

If you would like to know more about electric vehicles and the work of the Electric Vehicle Task Force, you can contact Jim Baak at the Bureau on 748-3944. The public can also contact John Huetter at CALSTART on 864-3006; Zebra Motors, Inc., (415) 884-5220; Kaylor Energy Products, (408) 338-2200; the Electric Vehicle Association of the Americas, (415) 249- 2690; or the California Electric Transportation Coalition (916) 552-7077.

CLIP and KEEP!

Important Bureau of Electricty contact numbers:

Customer Service......................748-3900
General Information 748-3901
After Hours/Emergency 748-3902
TDD (hearing impaired).............522-7538
E-Mail....102607.2043@COMPUSERVE.COM

THE NEW ELECTRIC FLASH is published as a service to the customer/owners of the Bureau of Electricity/City of Alameda. Readers are invited to submit ideas, suggestions or questions by writing the Editor at the Bureau of Electricity, P. O. Box H, Alameda, CA. 94501-0263.

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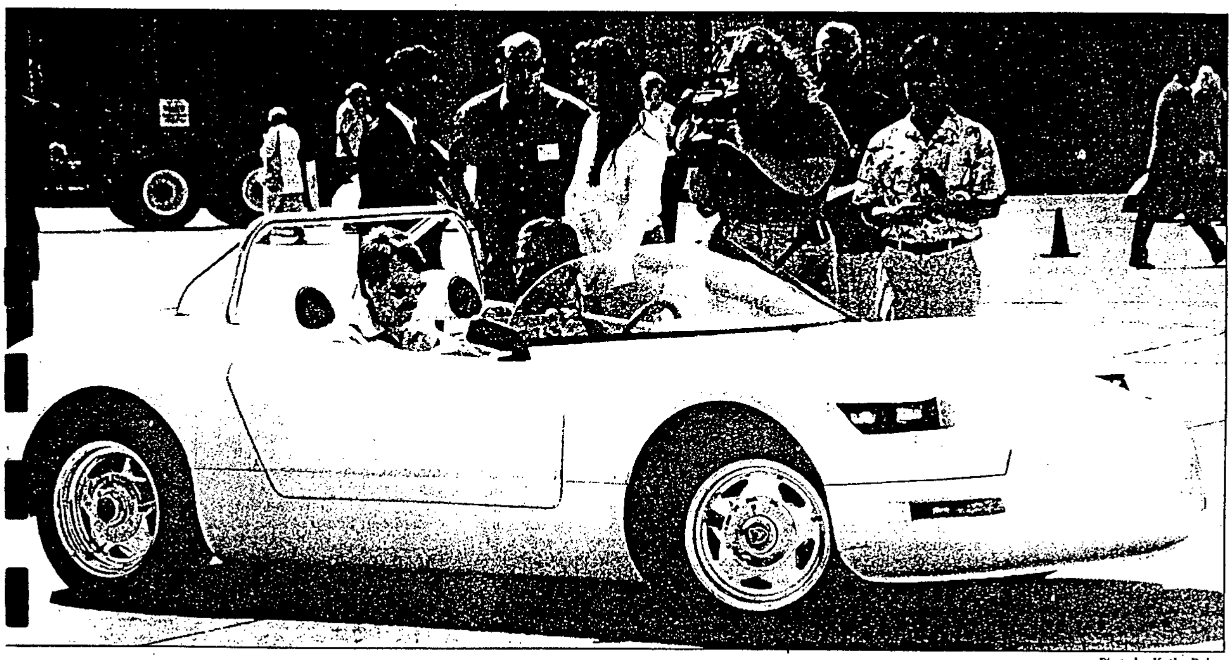


Photo by Kathy Baker

le, an Alameda High School graduate who is now vice president of ring for Zebra Motors Inc., (in passenger seat) accompanies a visitor st drive of his company's nearly silent electric sports car at the CALSTART open house July 22. The event celebrated the establishment of the advanced transportation technologies "hatchery" at Naval Air Station Alameda.

ALSTART hatchery 'just the beginning' at base

Quigg

e engine driving base redevelop- is almost silent, but that doesn't it's not working.

a couple dozen electric hatch- nvertibles and sedans decorat- orking factory, the CALSTART nced transportation technology" rtium welcomed civic, business and nment leaders and the press to its n old aircraft hangar at Naval n Alameda.

TART Chief Executive Officer esident Michael Gage told about sitors to the hangar that his fledg- dustry is unlikely to cluster in one the auto industry did in Detroit, pects big things in Alameda.

is just the beginning," he said. strong belief that the Alameda Air Station can become ... a pres- ddress for the advanced transpor- chnology industry."

TART has only been at NAS since mber, when it became the first nant of the base reuse effort. then, the consortium has rented 70 at of the 70,000-square-foot hangar ious start-up companies.

The media buzzed around the City Bee electric car.

Termed a "hatchery," CALSTART's hangar is a place where these firms can try to make dreams of transportation innovation come true. So far, eight hopeful companies have brought 50 jobs to the base.

NAS Commanding Officer Capt. Jim Dodge predicted "more CALSTARTs and more opportunities" for the base.

Many credited Rep. Ron Dellums, D-CA, for hatching the hatchery at NAS. Sandré Swanson, who represents Dellums on the Alameda Reuse and Redevelopment Authority, said the entire effort prior to NAS's 1997 closure should show the rest of the country "you can breathe life into a base before it is closed."

Mayor Ralph Appezzato said he felt a new sense of hope in CALSTART's hangar.

"The future of our community is very bright indeed," he said. "... Just a few months ago this hangar was empty and there was no cause for joy and celebration ... We will succeed in converting this historic base into an economic engine that we in the region can all be proud of."

Another sort of engine was humming almost inaudibly shortly after the mayor's speech. Appezzato took the Zebra Model Z out for a test drive. The Novato company that makes the sleek convertible electric sports car is considering a move to CALSTART's hatchery.

Appezzato was enthusiastic after his brisk spin.

"Those who can afford to purchase an electric vehicle should," he said. "They

see CALSTART, page 12

CALSTART

continued from page 1

look like and feel like you're driving a sports car."

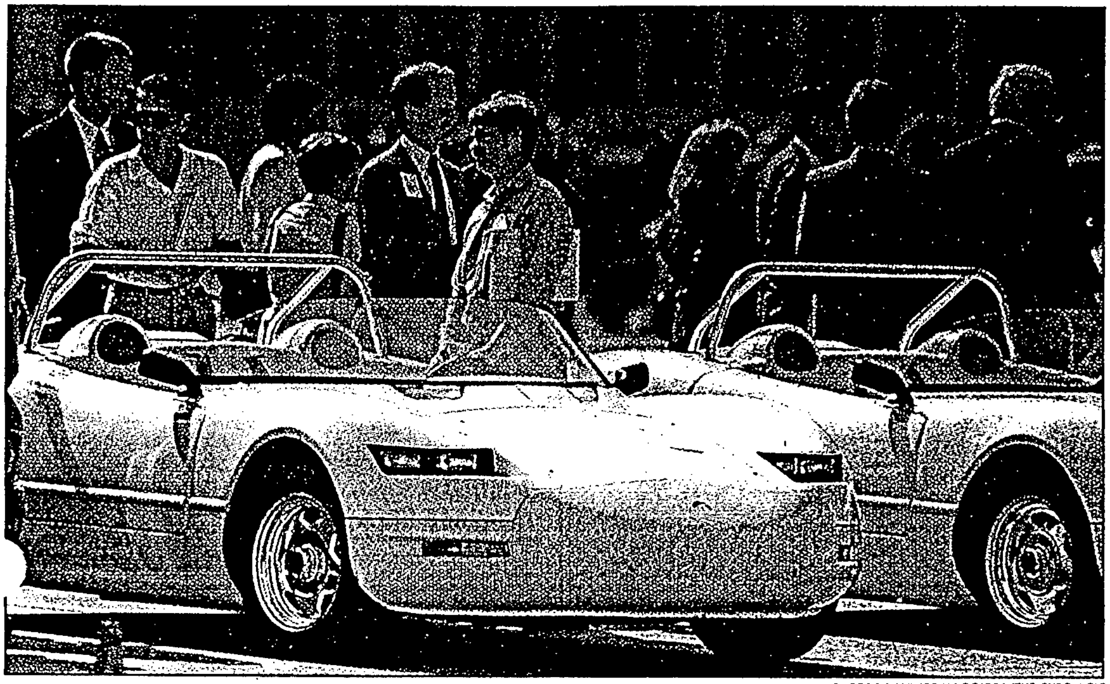
Calling the vehicles ideal for the island, he had similar optimism for the hatchery.

"This is a concrete example that this air station can be productive and can be an economic rebirth for the region," he said, adding that the hatchery need not have a perfect record with the firms it brings to the island. "If just one succeeds, it will be a success."

Reuse authority Executive Director Kay Miller said she expects CALSTART's hatchlings to expand to other base facilities as they grow. She added that her office likes the hatchery concept and is interested in using it again with biotechnology, environmental, telecommunications and motion picture companies.

"We think this is a perfect model for the kind of things we'd like to expand upon here," she said.

San Francisco Chronicle
TUESDAY, JULY 23, 1996



PHOTOS BY VINCE MAGGIORA/THE CHRONICLE

Zebra Motor Inc. of Novato showed off its two-seat electric sports car at the Alameda Naval Air Station

An Electrifying Conversion

Clean transportation startups hatched at Alameda air station

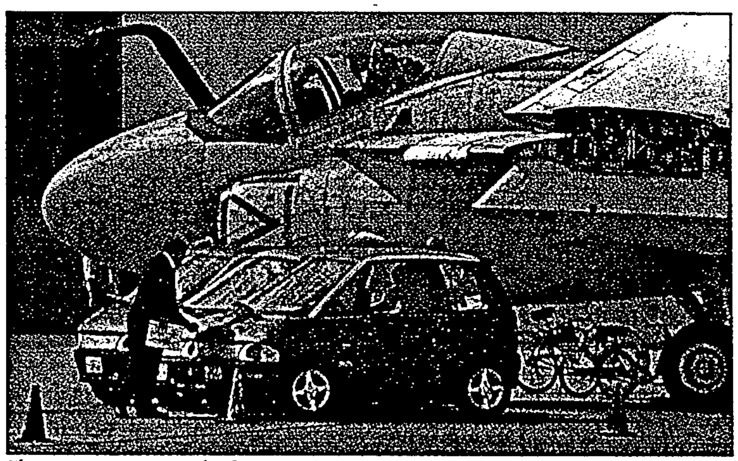
By Jonathan Marshall
Chronicle Economics Editor

Looking out on million-dollar views of San Francisco and the Bay, dozens of government officials, engineers and curious citi-ens zipped around the Alameda Naval r Station airfield yesterday in electric .rs.

The occasion was the first open house of a business incubator center housing eight small companies in the clean transportation field. These start-ups are pioneering the conversion of the 1,842-acre Alameda Naval Air Station to civilian uses, before the Navy finishes its pullout next April.

Located at the air station's Hangar 20, the center was opened only about six months ago with the help of a $2.5 million federal grant from Calstart, a non-profit consortium dedicated to advancing transportation technology in California.

Already the incubator employs 50 .ad is three-quarters leased. An A-6 Intruder aircraft parked just outside, with its wings folded, is the only reminder that military jets were once housed in the 65,000-square-foot space.



Electric cars were parked next to an A-6 Intruder at the air station

"Just a few months ago this hangar was empty and the mood was solemn," said Alameda Mayor Ralph Appezzato. "Thanks to Calstart we have a hangar full of vibrant activity, full of hope and optimism."

The idea behind business incubators is to create synergies by putting small companies in the same industry side by side.

Calstart has created a similar business incubator for clean transportation companies in its hometown of Burbank. That site now has 25 businesses.

Michael Gage, president of Calstart, said both should prove viable. "Alameda can become a center and prestige address for the advanced transportation technologies industry," he said.

The U.S. Defense Department has helped fund some of the technology that was on display at yesterday's open house.

Thanks to a grant from the Defense Department, engineer Lee Ackerman, who works out of the hangar, just perfected a DC-motor controller that could slash the cost of high-performance electric vehicles. He's close to signing a sales agreement with Zebra Motor Inc. of Novato, which gave participants at the open house high-speed test drives of its snazzy, two-seat sports car.

Zebra also may relocate to the naval air station, but is considering incentive

ELECTRIC: *Page C5 Col. 1*

ELECTRIC: Station's Conversion

From Page C1

packages from other California cities, said Gary Starr, who helped found it along with an electric bicycle company, Zap Power Systems of Sebastopol.

Its car, which proved a hit with the crowd, will retail for about $20,000 in full production. It's not the most practical car, Starr conceded, but it's eye-catching and peppy. You may not be able to go 400 miles in the Zebra, he said, "but you should at least have fun for 40 miles."

A more pedestrian-looking two-seater will become available this month to patrons of the Walnut Creek and Colma BART stations, thanks to Green Motorworks, a North Hollywood electric vehicle marketer that has space in the Alameda hangar.

Earlier this year, more than a dozen of its small electric cars were stationed at the Ashby BART station, where they have proven a hit with employees of Sybase and other companies that lease them for local trips. "We don't have enough cars for everyone who wants them," said William Meurer, president of Green Motorworks.

Green's cars will come with dual air bags, travel up to 60 miles per hour and have a range of about 60 miles on a battery charge when they go on sale to the general public next year for about $15,000, Meurer said. For customers with more traditional design tastes, Meurer also had electric conversions of an Alfa Romeo Spyder and a Ford Escort station wagon on display.

With General Motors scheduled to begin selling its sporty, two-seat Impact electric car next year, these and other startup companies in Alameda hope to ride a wave of growing public interest in quiet, nonpolluting vehicles.

But Meurer conceded his firm, and the industry as a whole, needs some breakthroughs in range and cost before electric vehicles will become big sellers. "We cannot provide a replacement for the gas car right now," he said.

The Oakland Tribune.

Tuesday
July 23, 1996

·LAURA A. ODA — Staff

e City Bee, a Norwegian electric commuter car, is dwarfed by a jet at Alameda Naval Air Station on Monday.

ir base gets jump start on civilian life

Kathleen Kirkwood
WRITER

ALAMEDA — Electric-pow-d cars of all shapes and sizes d around the runways ay at Alameda Naval Air n, giving test drivers a taste he future.

"efinitely, I would buy one," emonia Bowie, after a ride the quiet base in a sporty-looking electric "Tropica."

Bowie said she would trade in her Mercury Sable for the noiseless little car. The deciding factor came down to the cost of fuel. Charging the Tropica costs about $1.25 for every 100 miles.

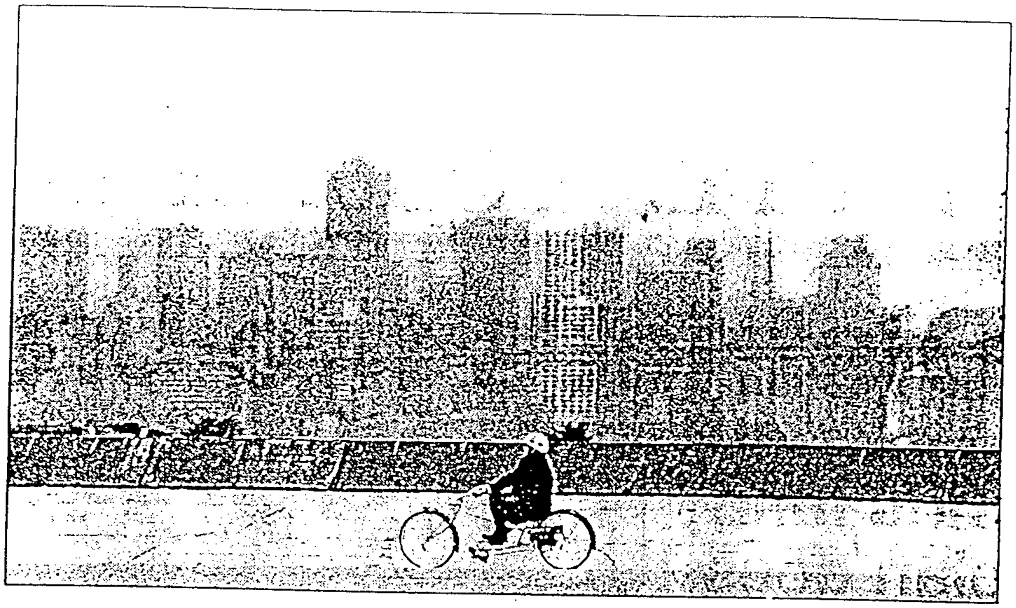
"It's exciting, easy and it's under $20,000," said Bowie, who works for Communications Technology Cluster of Oakland. "I want it."

Built by Zebra of Novato, the Tropica was one of two dozen "alternative-fuel" vehicles — including scooters, bicycles and even a few custom-fitted shopping carts — parked on the base's runway.

They were lined up around a Navy A-6 Intruder jet to symbolize the ongoing transition of the base from military to civilian use. The base is due to close down entirely in April 1997.

The occasion was the grand opening of CALSTART's business incubator in a 65,000-square-foot hangar at the base. There are now eight firms housed

Please see **Conversion**, A-12



LAURA A. ODA — Staff

Jerry A. Martin of the California Air Resources Board takes a low-riding electric-powered bicycle for a spin along the Alameda Naval Air Station runway.

Conversion: Potential plentiful

Continued from A-11

there, with about 50 employees using surplus machine tools and equipment that's being left behind by the Navy.

"Just two years ago, this hangar was empty, the mood was solemn and there was no cause for joy and celebration," Mayor Ralph Appezzato said.

Appezzato said the CALSTART activity brings "a new sense of hope and optimism" to base conversion efforts.

About 200 people attended the event, many of them entrepreneurs whom CALSTART hopes to lure to the center, which they are calling "Project Hatchery North." CALSTART is a consortium of 200 state firms and agencies, based in Burbank

Lon Bell, CALSTART's founder, said the goal was to bring together entrepreneurs with advanced transportation technology ideas together, and give them a jump start.

"Hatcheries work. Hatcheries spawn new industry," said Bell, who is the president of Amerigon Inc., the largest firm located at the Alameda CALSTART hub.

This month, Amerigon started shipping out electric car "kits," partly assembled at the base, for companies in Asia. Crates containing the kits for Amerigon's "EV-4" were lined up in the hangar.

Other models on hand at the base were the Norwegian-built "City-Bee" and "Citi," small commuter cars that are now being used in a BART electric car demonstration program.

"The thing that's amazing about them is they are so quiet. You could drive up on someone and they wouldn't hear you coming," said Gene Keller, marketing director for the Alameda Bureau of Electricity.

Steve Skarry, owner of Island Auto Sales agreed, after test-driving the Tropica. "I can wait for them to come on the used-car lot so I can sell them."

The CALSTART hub, modeled after a cluster of 19 CALSTART firms in Burbank, could create 400 jobs by December 1996 and has the potential to employ thousands by capturing the wave of new and alternative transportation technology, according to CALSTART officials.

Alameda Journal 6/10/97

Consortium offers helping hand

Mayor Ralph Appezzato was on hand recently to congratulate the members of the Alameda Education, Technology and Business Consortium as they approved the new group's by-laws and elected officers during a meeting held at College of Alameda.

The consortium, composed of educational providers, research institutions, technology transfer organizations and service agencies, will be a one-stop source for development of education and training for emerging technologies and industries in Alameda and the surrounding region, according to the organization's new secretary, Juan Vazquez, dean of instruction at the local community college.

Other officers elected on April 11 were John Huetter, director of project hatcheries for CALSTART at Alameda Point, president; and Mack Lovett, assistant vice president of California State University, Hayward, treasurer.

Founding consortium members include CALSTART; Alameda Center for Environmental Technologies (ACET); California State University, Hayward; College of Alameda; and the Alameda Unified School District.

Additional information can be obtained from Andrea Safir at (510) 748-2108.

San Francisco Chronicle
NORTHERN CALIFORNIA'S LARGEST NEWSPAPER
FRIDAY, APRIL 25, 1997

Alameda Base Closes Today, But Space Won't Sit Empty

Electric cars, Disney among the 18 tenants

By Kevin Fagan
Chronicle East Bay Bureau

Jeff Gile peered out across the vacant Alameda Naval Air Station blacktop, where not long agò a huge fighter jet would have sat blocking out the sun, and smiled. There was nothing but waves between him and a crystalline shot of the San Francisco skyline.

"I've got a million-dollar view, lots of pavement and nothing to get in the way of my test drives," said Gile, trudging back into the CalStart electric car factory where he designs sports cars. "Empty and quiet, just the way I like it."

It's going to get a lot emptier today when the air station hauls down its flag, ending 57 years as the centerpiece of U.S. Navy firepower in Northern California. But if civilian conversion planners have their way, the island base just off the shoreline of Oakland won't

ALAMEDA: *Page A17 Col. 1*

FRIDAY, APRIL 25, 1997

ALAMEDA: Base Closes Today

From Page 1

stay that way for long.

The Navy is leaving 1,684 acres that include a steam-driven electric power plant, sports complexes, cavernous warehouses, homes and three deep-water piers — and there is a shipload of hopes and fears about what to do with them.

Hollywood moviemakers, small industries, a tiny fleet of ships and an endangered bird — the least tern — have already staked claims to chunks of the base. And with $1 million in annual lease revenue already coming in, plus $4 million in federal redevelopment grants, the Alameda Reuse and Redevelopment Authority is well-armed to entice more business and get projects rolling.

"I don't think you'll find another base in the nation right now with this amount of civilian reuse already before we've officially shut down," said Kay Miller, director of the base reuse authority. "I think it's amazing what we've done so far."

Alameda has already been the most successful conversion model among the five major Bay Area naval bases ordered shut since 1989, attracting as many businesses as the other big base, Mare Island in Vallejo. And Mare has been closed a year.

Eighteen business or government tenants have signed on to use parts of Alameda, from Disney Studios — which shot the film "Flubber" there last year — and the Quality Assured Products industrial valve factory to the CalStart electric car consortium. The most visible outfit to take up residence is the federal Maritime Administration's Ready Reserve fleet of 11 transport ships, used for disaster relief and military support.

In all, about 900 civilian jobs have been created at the base. And with 525 acres of wetlands marked as refuge for the least tern and other wildlife, the environmental use of the base is also well on its way.

Plans include a new sports complex for Alameda, a public golf course, a regional park and a development of houses and marine businesses around the former seaplane lagoon. Some 1,500 units of base housing are still usable. The Coast Guard and a homeless transitional housing group have snapped up about half of the houses. Among the warehouses ready for use is a mini-aircraft factory called Building 5, with a million square feet of space.

But for all the activity, the real work of replacing 20,000 civilian and military jobs and the millions of dollars they meant to the region has only begun.

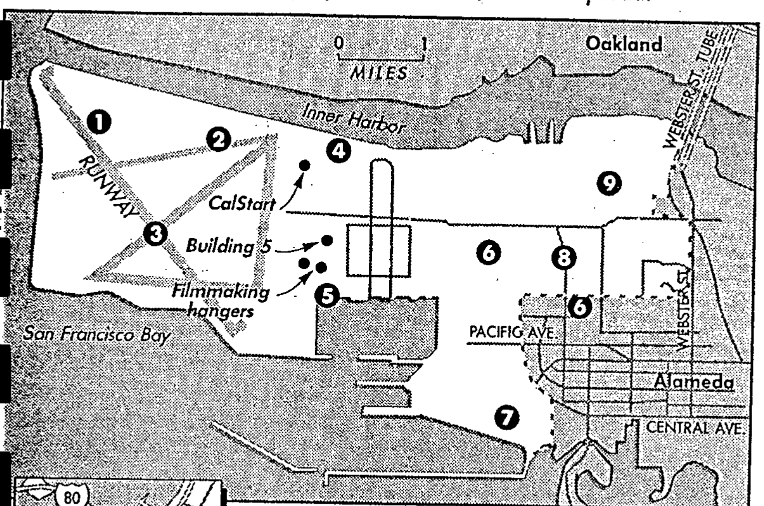
Still to be done is as much as $200 million worth of cleanup of toxic waste and a lot of salesmanship and tricky negotiations between the governmental agencies that have some claim on the land. The reuse authority may be overseer, but its decisions must be finessed through the many governments it represents — including Oakland, Alameda and Alameda County — as well as other agencies such as the East Bay Regional Park District and the federal government.

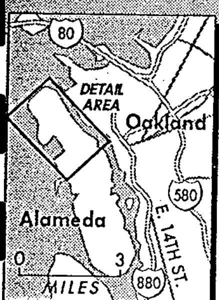
If all goes well, the station will become the model of civilian conversion President Clinton said he hoped it would be when he ordered it shut in 1993. If not, there will be a lot of rotting buildings and an economic body blow to Alameda, which has already seen some Navy-dependent businesses shut and its school population dip

CONTINUED FROM THE FRONT PAGE

ALAMEDA NAVAL AIR STATION PLANS

The Navy turns the 57-year-old base over to civilian use today. Here are some of the conversion plans proposed for the 1,684-acre spread.

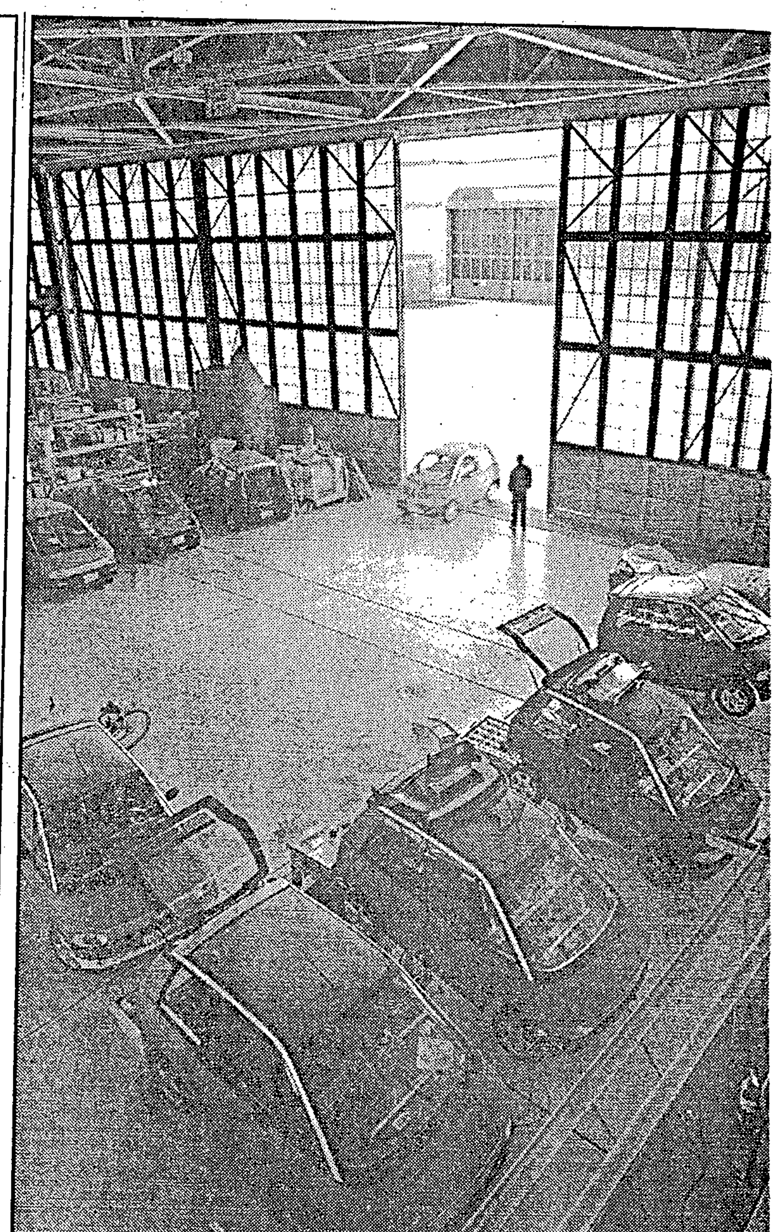




■ Proposed uses
(Alameda Naval Air Station uses in italics)

- ❶ Golf course *(Landing strip)*
- ❷ Small research firms *(Landing strip)*
- ❸ Wildlife refuge *(Landing strip)*
- ❹ City sports complex
- ❺ Marina and related development *(Seaplane lagoon)*
- ❻ Homeless housing
- ❼ Regional park
- ❽ 1,500 housing units
- ❾ Coast Guard units

CHRONICLE GRAPHIC



BY MICHAEL MALONEY/THE CHRON

Green Motorworks Inc. has set up an electric car plant at Alamed Naval Air Station. The air base officially closes today

,000 military families left.

We're keeping our fingers ;ed, even though we've al- ly seen a slight drop-off in cus- ers," Linda Costello, who co- the McGee Bar and Grill in ieda, said yesterday. "We've :d a lot of different ideas, but oo early to tell what the clo- will do.

All I know is tomorrow will be 1 day."

e base already looks empty, most of its 200-plus buildings tered and the once-teeming :aft tarmacs and ship piers y idle. It started to look that last summer, when the air- field and then the Naval Aviation Depot shut down. It assumed a fuller silence in January, when the aircraft carrier Carl Vinson steamed away.

A citizens group is trying to keep the base's legacy alive by turning the retired USS Hornet — now tied up at one of the station's piers — into a floating museum.

Base commander, Captain Jim Dodge, said he's still incredulous that the base is shutting down, but he's upbeat about the future he's handing off to civilians.

"This place is in fine shape for them to make use of, and I am sure everyone will be pleasantly surprised," he said this week at his office, boxes piled in the hallway. "We've cleaned a lot of things up, the buildings are ready to occupy, and we are leaving a deep legacy of military history that I am si will be preserved.

"We think the chance of t base turning into a ghost towi just about nil."

Plugged In

Electric Vehicle Expo shows Alameda is focused on the future

By David Quigg
Staff Writer

When bigwigs start buying you lunch, it may be time to consider taking yourself seriously.

At a gathering to promote the Alameda Electric Vehicle Exposition, representatives of General Motors, Ford, Honda and a collection of advanced transportation companies sat down to a meal hosted by Toyota.

But it was something that the people from Toyota and the other massive carmakers said during a panel discussion just before lunch that boosted the credibility of the Bureau of Electricity's newest ambition: making Alameda a model city for electric vehicles.

Asked whether they could envision a day when their companies' assembly lines would turn out as many electric cars as gas cars, nobody said no. Ford jumped right in: "Yes." Bowing to the market, GM's Rick Ostrov said, "Yes, if you desire it." Toyota and Honda gave answers that boiled down to "maybe."

"I never expected to hear that from the majors," John Huetter, director of CALSTART's advanced transportation hatchery at the closed Naval Air Station Alameda, said later.

However tepid an endorsement "maybe" might seem, GM's Ostrov said the responses were remarkable. Even two years ago auto industry representatives would have laughed at the suggestion that electrics could one day pull even with gas cars, he said.

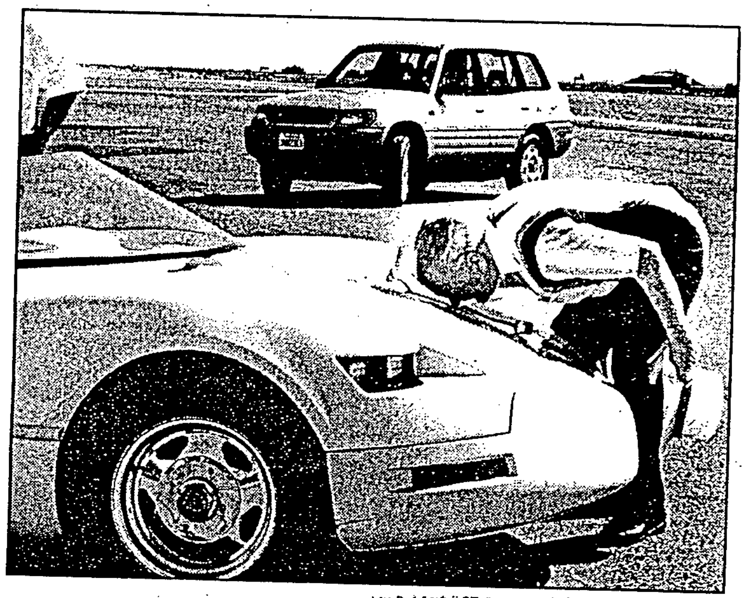
And here they were — representatives of four of the world's biggest carmakers, sitting in a tent pitched on the runway of the closed Navy base, getting ready to go outside and show off their early efforts at bringing electric vehicles to American consumers.

But something is standing between electric vehicles and the mass market.

"The only way this technology will begin to succeed rapidly is if we really get the public infrastructure in place," said Ostrov.

In any American city, you don't have to drive far before you come upon a gas station and then another and another. The same cannot be said of public places to charge an electric vehicle.

Janet Orth of Willits (above) slips behind the wheel of a General Motors EV1, while Hiroyuki Narashima (left) takes one of Electric Motorbike Inc.'s motorcycles for a spin. Richard Myer of Alameda (below) peers inside the body of a Zebra Motors electric sports car. Myers said he would be interested in buying one next year.
— Photos by Kathy Baker



That's where the Bureau of Electricity comes in, according to Jim Baak, who oversees the city-owned utility's Electric Vehicle Task Force.

Between the two sponsors of the Sept. 27 electric vehicle expo, Alameda already has eight public-access charging stations — two at the bureau and six at CALSTART.

As more citizens buy electric cars, expect more charging stations to pop up around the island. In its effort to make Alameda a model electric vehicle city, Baak said the bureau is looking at installing stations at City Hall, the ferry terminals and South Shore Center. As always, budgets will dictate how fast this can happen.

Things may be moving faster than anyone expected, according to Baak. He said the companies represented at the expo were surprised that so many people showed up to try out their vehicles.

With a startlingly beautiful view of San Francisco as the backdrop, an estimated 3,000 people spent their Saturday on the old NAS runway taking a peek at the future of transportation.

What they saw and drove may have been a revelation. It turns out electric vehicles are not just

see EXPO, page 10

Expo

continued from page 3

more of the same, not just wannabe gas cars.

"Most sane people who are in the electric vehicle industry will tell you it's not a replacement for the gas car," said BofE's Baak.

But many of the trips we make in gas cars are overkill, he said. For example, there is the commonplace sight of someone taking a sport utility vehicle to pick up a bag of groceries.

Ambitious young companies are crawling into the various niches where gas cars are overkill.

The expo featured bicycles with electric motors to help commuters conquer the headwinds and hills, electric skateboards, electric scooters and electric motorcycles. For tooling around town, there were what amounted to souped-up golf carts.

For those who insist on taking their sport utility vehicle to the supermarket, Honda and Toyota were on hand with electric versions. Honda used the expo to announce that it is bringing its EV Plus to the Northern California market. Ford brought an electric version of one of its pickup trucks.

And for those who worried that electric vehicles have to look like Tupperware on wheels, there were a couple of very sleek cars. Zebra Motors, which is close to signing a lease on space at NAS, was giving test drives of its sporty white convertibles. General Motors was showing off the EV1, which hurries from 0 to 60 mph in 8 1/2 seconds.

The expo is making some big noise for Alameda, according to Baak. Talking two days after the event, he said he was getting ready for interviews with a French magazine and Minnesota Public Radio. In addition, he counted five television stations, two radio stations and a whole host of newspapers that had covered the expo.

"We're getting coverage all over the place," he said. "It's unbelievable."

Plans call for an even bigger expo next year.

Thousands turn out to see electric cars

By Jonna Palmer
AFF WRITER

ALAMEDA — It was almost like watching a car rally on ute. Brightly colored cars pped around the airstrip at Alameda Point Saturday afternoon giving most riders their first test ive of an electric vehicle.

It was all part of the Alameda Electric Vehicle Exposition.

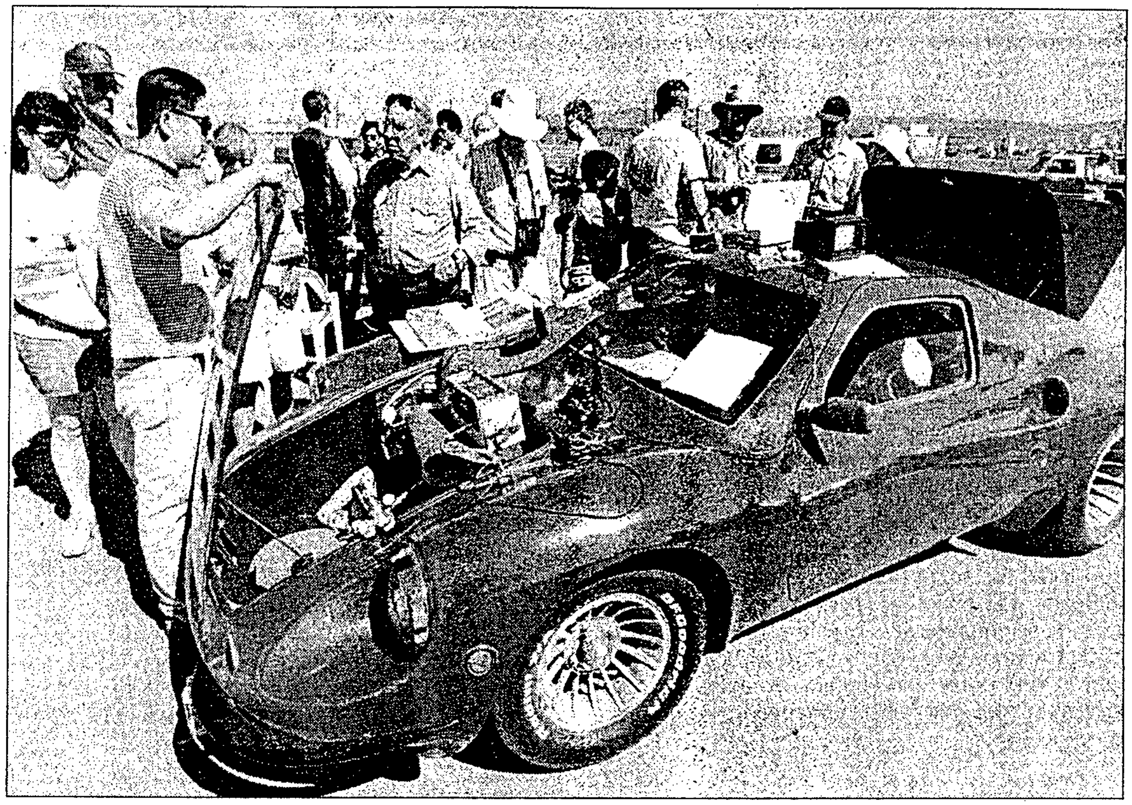
Organizers said they were exemely pleased with the rnout — about 3,000 people — and hoped the public would take home the message that ectric cars now are a practical ernative to gasoline-powered vehicles.

The expo featured a variety of ectric vehicles for people to st drive — everything from Toyota's RAV-4 EV to converted Volkswagen Rabbits to an ectric-powered Radio Flyer gon.

Jim Baak, who helped coordinate the event for the Bureau Electricity, said the expo feaed the widest variety of lectric vehicles ever gathered in alifornia.

"I think people will come out it with the realization that his is no longer future techology," he said. "It is a 'now' hnology."

And that is even more true in he Bay Area now that Honda as decided to lease its EV US at three local Honda dealhips. This week, the auto nanufacturer announced the V PLUS would be available t. 1 for fleet sales in the Bay ea, but Christian Nguyen of San Francisco Honda said the cars also would be available for individual leases.



JANE TYSKA — Staff

Visitors to the Electric Vehicle Expo check out a car that runs on hydrogen fuel cells and surge batteries.

John Heutter, director of Alameda's CALSTART incubator, said it was a good sign that Honda is following customer demand.

"You have some major players that are being responsive (and taking) some risk to get the vehicles out there," he said.

With the Toyota RAV4 EV and GM's EV1 also offering test drives, consumers had at least a few examples to compare with Honda's car. But several of those who took test drives instead compared the cars with conversion cars owned by members of the Electric Auto Association.

Jim and Dorie Krantz said they are looking for a second car to buy and are interested in an electric car, but balked at the expense of leasing a new one, which they said would cost about $500 a month. Jim Krantz said the idea of converting an older car was much more appealing because it would be less expensive.

Motorists take a quiet spin in electric cars

BY RENEE KOURY
Mercury News Staff Writer

ALAMEDA — Hundreds of drivers zoomed around an old runway at the defunct Alameda Naval Air Station on Saturday, but they could still hear the distant call of the gulls and smell the salt in the sea breeze.

The vehicles hardly made a sound. And they didn't smoke up the air.

The drivers were in electric cars at the Alameda Electric Vehicle Exposition, the first major event of its kind in the region, organizers said.

"They look like regular cars," marveled Tina Monaco-Glynn of Oakland, who drove a Toyota Rav 4 Electric Vehicle. "The amazing thing was, you could still hear the wind while you were driving."

Doree Miles of Alameda was equally stunned by the lack of vrooming. "You don't even know the car is on," she said after test-driving a General Motors electric

See CAR, Page 6B

'They look like regular cars. The amazing thing was, you could still hear the wind while you were driving.'

— Tina Monaco-Glynn of Oakland, who drove a Toyota Rav 4 Electric Vehicle.

Motorists impressed by electric cars, but still have their doubts

■ CAR
from Page 1B

sports car. "It's so quiet. You don't have the gas pedal revving the car up or the exhaust coming out."

Throughout the day, about 3,000 curious drivers wandered into the exposition to examine the latest in electric-car technology. They were amazed to find sports cars and family cars that looked like regular cars, and an assortment of motorized bicycles, scooters and motorcycles. Everyone wondered if the clean and quiet cars were really available for purchase, how much they cost, how far they can go before the batteries poop out and how fast they run.

"A lot of people don't believe they're really market-ready yet, and they are," said John Huetter, a director of Calstart, a consortium of companies creating clean-engine transportation. Calstart has its headquarters on the old Navy base, which closed in April.

The bigger electric cars sell for about $30,000, according to manufacturers, or about $400 to $500 per month to lease. "Too bad they're so expensive, or I might consider it," said Monaco-Glynn, echoing other test drivers. "I like the cars, but it's so much money."

Others were concerned because the cars usually can go only 100 to 125 miles before the batteries run out of juice. Recharging usually takes around six hours. And most electric cars go a little slower than gas-driven cars, though big ones can reach 80 mph.

Only a few big manufacturers, such as Honda and General Motors, plan to start distributing their electric cars in Northern California soon, and only a few vehicles — tested in Souther California — will be available.

Norway's Pivco, the company that makes those little electric "city bees" that BART riders can borrow to drive from train stations to work, also has made those cars available for sale in the region, event organizers said. And some bicycle companies, such as Zap Power Systems of Sebastopol, sell motorized bikes that can reach up to 18 mph and come with rechargers.

'I have a feeling I'd get stuck somewhere with an electric car that went dead, and where . . . would you plug in?'

— Terri Connors

About 15 manufacturers of electric bikes, cars and motorcycles lined up their wheels Saturday and let anyone with a driver's license test drive for free.

"I was very impressed," said Bob Spoer of San Francisco, a high-tech recruiter, after he rode in GM's sporty, red, two-seat EV1. "It was sort of like a leap into the future. The main advantage is, it's so quiet. And you're driving with a clean conscience."

Car manufacturers have an interest in creating a desirable electric car. Under a California clean air mandate, starting in 2003, 10 percent of vehicles offered for sale in California must have zero emissions.

Officials from the city of Alameda, which co-sponsored Saturday's expo, have tried for years to get more people to drive electric cars to keep the community cleaner, said city spokesman Matt McCabe. Officials are urging electric car companies to settle on the former Navy base — a 1,734-acre swath of land that McCabe said is perfect for research and development.

Many drivers, while wincing at the prices for the cars, said they'd buy them to help clean up the air.

"When you're driving a truck all day long up and down the freeway, you look on the horizon and see nothing but yellow, and you start to feel so guilty," said Mike Connors of Alameda, a driver for an East Bay coffee company. "The warning signs of pollution are here. We have to listen."

But many said they'd use the cars only as a secondary family car for short jaunts. "I personally love them, but I'd like a transition period where there are cars with both gasoline and electricity," said Connors' wife, Terri. "I'm still a little leery. I have a feeling I'd get stuck somewhere with an electric car that went dead, and where would you go? Where would you plug in?"

Friday
Alameda Journal
Published every Tuesday and Friday ■ 25¢
September 26 - September 29, 1997 ■ Volume 11, Number 77

— Photo by Kathy Baker

It's silent, it's tiny, and the Alameda Bureau of Electricity believes it may very well be in your future. A prototype CitiBee electric vehicle is dwarfed by its full-sized gas-burning cousins.

Alameda looking to become the leader in the electric vehicle industry

By Janet Kettelhut
Staff Writer

If Jim Baak has his way, Alameda will be humming.

"What the Silicon Valley is to computers and what Napa is to wine making, we want Alameda to be to the electric vehicle industry," said Baak, the Bureau of Electricity's electrical vehicle program coordinator.

The island could be a Northern California center for their development, production and use.

"Alameda is the ideal community," he said. "They work best in mild climates, at low speeds and with short driving distances."

But even though they were first built over a century ago, and the idea was revived during the 1970s gas crises, electrical cars have yet to catch on.

"Most people think they are like golf carts and that they can't go far or on freeways," said Pleasant Hill's Anna Cornell, a member of the board of directors of the Electric Auto Association that promotes the use of electrical vehicles. She and husband, Scott, have traveled for years speaking with thousands of people about their two converted Volkswagens — a Rabbit and a Karmann Ghia.

But she says misconceptions abound. Scott has driven his electric vehicle for 17 years. He drives 40 miles on the freeway to his job in San Ramon.

They travel at 80 miles per hour and have traveled from San Francisco to Eureka stopping at three recharging stations set up for a special event. But for most long trips, such as to Tahoe, people will need a gas vehicle.

But using gas-powered cars for short trips is like swatting moths with a ray gun.

"It's wasteful to hop into a Ford Explorer to go 1 1/2 miles to pick up your groceries," said Baak. "It's harmful to the environment — the emission system is not warmed up and pollution is at its max — and it is not cost effective."

An electric vehicle would be perfect. According to a survey of commuters into Alameda, the average worker travels 36 miles, well within the range of a battery operated auto.

Right now the bureau and the city have about seven electric vehicles in their fleet of 100.

Switching to electric may prove easier for the city than for its citizens.

"Americans have a great attachment to cars that are bigger, better and faster," said Baak. "And we also love the luxury of CD players, and electric doors and windows in our cars."

Electric vehicles themselves have been something of a luxury.

"Like any new technology it's very expensive — almost double the cost of gas vehicles," said Baak.

But that may be changing.

Alameda's Zebra Motors, Inc. is developing a sporty vehicle — a two-seat convertible that looks like a cross between a Corvette and a Mazda Miata — that will sell for $20,000 .

"Their claim to fame," said Baak, "will be the world's first low-

see ELECTRIC VEHICLES, page 8

So what's it like to drive one?

By Kathy Baker
Photographer

"So Kathy, what do you say? You want to test drive one of the electric CitiBee cars?"

Since I do more driving than most of the other editorial staff, and had secretly been dying to drive one, I said, "Yeah, sure!"

I contacted Jim Baak at the Alameda Bureau of Electricity, who is in charge of the electric vehicle program.

To my delight, "When do you want it?" was the answer to my request.

The day came when I was to

see DRIVE, page 8

Alameda Electric Vehicle Expo

On Sept. 27, the island goes public with a bold idea – making Alameda the West Coast hub of the electric vehicle industry.

The long-planned coming out party comes in the form of the Alameda Electric Vehicle Exposition. Scheduled to exhibit are household names such as Toyota, Honda, Ford and General Motors, as well as fledgling Alameda firms hoping they will soon become just as well known.

From 10 a.m. to 4 p.m. at the closed Naval Air Station Alameda, the public will be able to test drive electric vehicles, see demonstrations and attend a rally sponsored by the East Bay Chapter of the Electric Auto Association.

The setting is fitting, since the closed base is home to the CALSTART consortium's "hatchery" – a place where a variety of "advanced transportation" companies are getting their starts.

Organizers certainly hope

see EXPO, page 8

'What the Silicon Valley is to computers and what Napa is to winemaking, we want Alameda to be to the electric vehicle industry,'

– Jim Baak

Electric vehicles

continued from page 1

cost electric sport car."

It is expected to be ready for sale in Alameda next year.

Upcoming mandates by the California Air Resources Board are pushing more manufacturers to build cars with zero emission. That's getting mainstream builders like GM, Honda, and Toyota into the business.

Toyota's RAV4 EV will look like it's gas-powered sports utility vehicle. "And unless you hear it, or I should say didn't hear it," said Baak. "You couldn't tell it is an electrical-powered vehicle."

Another Alameda company, Green Motorworks, is negotiating with General Motors to bring six of their GM EV1s to the Bay Area.

And the bureau is planning to buy electrical vehicles so residents and business can borrow them for up to a week.

They want to introduce people to the car to overcome the misconceptions. Once they do, they may get hooked like Cornell and her husband.

"I like not having to go the gas station, no fumes and doing my part for the environment."

It Keeps Going and Going and...

NICK LAMMERS — Staff

A world distance record was set late Wednesday at Alameda Point when an electric car drove more than 1,000 miles on a single battery charge since Saturday morning. The previous record was about 400 miles. Strong off-shore winds delayed its planned finish time on Tuesday. The car was manufactured by Southern California-based company BAT International. "Electronic technology in the past has been growing by little increments, but this is a big increment," said BAT President Joe LaStella, who hopes to sell the car in heavily polluted countries in Asia. The company is now working on a two-wheel, battery-charged vehicle.

Spotlight

August 1996

News for the Customers and Communities We Serve

In This Issue • PG&E, Part of the Economic Community • Trees, Power Lines, and You • New PG&E Uniforms • Oriental Salmon

Why PG&E Trims Trees, And What You Can Do To Help

PG&E's New Look

Illustration by Winthrop Prince

Tree pruning is important and necessary. In fact, state law requires utilities to regularly prune trees from high voltage lines. PG&E spends an average of $50 million a year pruning trees, and has increased the budget for the future.

Take a moment to look at the overhead lines in your neighborhood. There are three lines to recognize—the primary or high-voltage lines, the secondary or low-

(continued on back page, col. 2)

PG&E Plays a Role In California's Economic Vitality

PG&E is not only the gas and electric company. We're part of the local economy in each community we serve.

To help make California a more attractive place to live and work, PG&E has created partnerships with other businesses, non-profit groups and community and government leaders through its Community Economic Vitality Initiatives.

In addition, PG&E employees have made contributions through a wide variety of volunteer and civic activities, such as being members of local economic development groups and chambers of commerce and by serving on planning commissions.

The company's Community Economic Vitality Initiatives are a commitment to ensuring California's communities are competitive in today's global economy. They are:

Small Business Development and Incubators

Business incubators are facilities where new and growing businesses operate under one roof, with affordable rents, flexible leases, shared services and equipment and access to professional management training and assistance. PG&E has helped to develop 20 business incubators which have created 1,100 jobs in northern and central California.

Strategic Community Economic Planning

PG&E has provided funding and leadership for organizations that are working to retain and attract businesses, generate jobs and promote strategic economic planning. These include the Tri-Valley Business Council, Joint Venture: Silicon Valley Network, the Bay Area Economic Forum and the Economic Vitality Corp. of San Luis Obispo County.

Military Base Conversion and Reuse

A base conversion effort is occurring at the Alameda Naval Air Station, where PG&E recently approved a grant for the Alameda Center for Environmental Technology (ACET) business incubator. It will be home to 25 small businesses that will take the information from environmental research facilities around the country and translate that knowledge into products.

PG&E also contributed a grant to CALSTART, an alternative energy incubator at Alameda with (so far) eight businesses that are manufacturing parts for electric vehicles.

Business and Community Climate Improvement

By working with local governments and other agencies, PG&E seeks ways to create business-friendly climates in the communities we serve. For example, PG&E co-sponsored a conference in northern California for local government and business to simplify the often lengthy permitting process for new businesses.

PG&E thinks these initiatives are a win-win proposition: stronger communities and markets mean a stronger PG&E. For more information about our Community Economic Vitality Initiatives, call the community relations department at (415) 973-7389.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ROD MILLEN SPECIAL VEHICLES
ACTIVE DIFFERENTIAL FINAL REPORT

Rod Millen

Special Vehicles

JOINT TACTICAL ELECTRIC VEHICLE DIFFERENTIAL DEVELOPMENT

ACTIVE DIFFERENTIAL

FINAL REPORT

CALSTART PROPULSION SYSTEM DEVELOPMENT PROJECT FOR ADVANCED HYBRID RECONNAISSANCE VEHICLES

7575 Reynolds Circle, Huntington Beach, CA 92647 Tel (714) 847-2111 Fax (714) 841-6839

JOINT TACTICAL ELECTRIC VEHICLE DIFFEREENTIAL DEVELOPMENT

ACTIVE DIFFERENTIAL FINAL REPORT

CALSTART PROPULSION SYSTEM DEVELOPMENT PROJECT FOR ADVANCED HYBRID RECONNAISSANCE VEHICLES

INTRODUCTION

As part of Rod Millen Special Vehicle's contract number MDA972-95-1-0011 (ARPA RA94-24 Program), effective April 1, 1996, under the aegis of CALSTART's *Propulsion System Development Project for Advanced Hybrid Reconnaissance Vehicles* effort, the Joint Tactical Electric Vehicle (JTEV) differentials were to be evaluated with the intent of improving the overall performance level of the vehicle.

BACKGROUND

JTEV's current drive system incorporates a Weismann locker differential system to allow the rotational rate of the wheels to vary from left to right across the vehicle, and allows the wheel with the most traction to receive the full driving torque available. This type of drive was selected for maximum mobility in an off-the-shelf system. This system has the advantage of always providing drive to the ground, but under very poor or rapidly changing traction conditions, it has the potential to overload the driving wheel and break traction, thus shifting all drive to the opposite wheel. This could cause instability due to the vehicle's tractive effort center rapidly alternating from left to right. In order to further demonstrate the tactical utility of hybrid electric vehicle technology, it was deemed desirable to attempt to improve the differential system with the intent of achieving a system capable of producing the absolute maximum tractive effort in all possible conditions, without adversely affecting JTEV's handling characteristics.

DESIGN SUMMARY

This project necessitated the design of a system capable of transmitting the full torque available at JTEV's differential through one wheel, and also capable of behaving as a completely open differential, inducing no torque bias across the axle. In addition, this system had to be able to fit in the space envelope available on JTEV, and be actuated by less than 1500 psi, so as to allow use of commonly available hydraulic components and seals. The torque transmission across the differential clutch pack was calculated to be approximately 225 ft-lbf, and the pressure to release the clutch pack was calculated to be approximately 750 psi. These calculations are detailed in Appendix A.

This project culminated in the design of a hydraulically actuated variable load clutch system capable of being fitted to JTEV. The unit consists of a set of friction discs and a hydraulic cylinder integrated in a very compact package. This clutch system is designed to function with a conventional, spider-gear type differential, and is intended to vary the torque transmission across the wheels on a given axle. The whole differential system is then to be integrated with a computer control through an hydraulic actuator. The control of differential slip allowed by this type of a system can give the vehicle maximum tractive effort (both in acceleration or climbing and also under braking) without introducing the poor cornering behavior associated with locked differentials. In the event of a loss of hydraulic pressure, this unit is designed to lock completely. This feature ensures that the vehicle maintains it's full drive capability. This situation would adversely impact the vehicles' cornering performance, but being able to pull out of the bog is more important than having optimum handling in tight corners. An assembly drawing and layout schematic is included as Appendix B.

Improving vehicle stability and traction using a computer controlled differential can be approached in a number of ways. The two most obvious are using a closed loop control system which simply attempts to equalize the torque transmitted by the left and right wheels of the vehicle, and an open loop control system which monitors operational parameters of the vehicle and regulates differential lockup with the goal of not impairing vehicle handling. Although a closed loop system seems a more elegant solution, such an approach is fraught with difficulties, including the difficulty of accurately and reliably monitoring axle torque, and the very real possibility of control system instability. For these reasons, an open loop control system would be the primary avenue of development for further work on this project.

TESTING

Bench testing of this unit was conducted to determine its ability to transmit torque, and it's ability to be pre-set to slip at different torque levels. The friction plates were lubricated with Mobil 1 15w-50 synthetic oil prior to assembly. The unit was assembled with varying shim stacks in order to vary the spring preload on the friction discs. Each assembly was then tested to determine its torque transmission ability. Torque transmission varied between 10 and 450 ft-lbf. Typically, static friction was five to ten percent higher than dynamic friction, but the dynamic friction measurements were not at all precise, especially at higher torque values.

Test results are summarized in Appendix C.

CONCLUSIONS

Bench testing shows that this unit as currently designed has the capability to function as the heart of an active differential system on JTEV. Further analysis is warranted prior to on-vehicle testing.

RECOMMENDATIONS

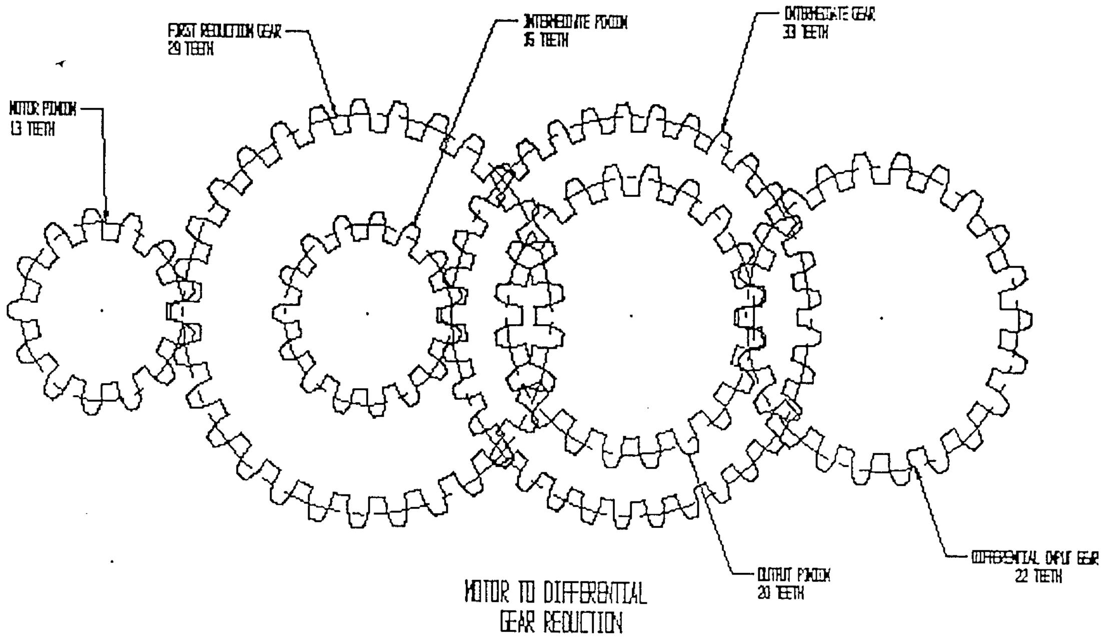
This system has the potential to improve the performance of the Joint Tactical Electric Vehicle under traction-limited conditions. Further analysis will be required to determine if the unit will be able to handle the thermal loading that might be imposed in the most severe situations. A number of options exist if the thermal issues prohibit use of this exact design. Among them are forced oil cooling through the clutch pack housing, and use of a heat exchanger in the hydraulic system.

Vehicle testing is required to validate the functionality of this system. The first phase of such testing should be to select and implement a suitable spider-gear differential, and then install the system on JTEV with only a rudimentary control system. This system should be able to produce no slip, 100% slip and 50% slip across the differential. During vehicle testing the system should be instrumented to evaluate thermal loading, torque split, and overall tractive effort.

APPENDIX A

Active diff torque and pressure calculations

JTEV Torque



$T_{motor} := 108 \cdot newton \cdot m$

$R_1 := \frac{29}{13}$ $R_2 := \frac{33}{15}$ $R_3 := \frac{22}{20}$

$T_{diff} := T_{motor} \cdot R_1 \cdot R_2 \cdot R_3$

$T_{diff} = 430.024 \cdot ft \cdot lbf$

Diff clutch torque req'd = 450 ft-lbf, based on JTEV

Clutch pack sizing:

$\mu := .1$

$M := \frac{450}{2} \cdot ft \cdot lbf$

$D := 4.0 \cdot in$

$d := 3.5 \cdot in$

torque transmitted through clutch pack is half of axle torque

$$M = \mu \cdot L \cdot \frac{D^3 - d^3}{D^2 - d^2}$$

$$L := \frac{-M}{\left[\frac{-\mu}{\left(D^2 - d^2\right)} \cdot D^3 + \frac{\mu}{\left(D^2 - d^2\right)} \cdot d^3\right]}$$

L=axial load required on clutch pack

$L = 4.793 \cdot 10^3 \cdot \mathrm{lbf}$

$D_{cyl} := 3.0 \cdot \mathrm{in}$

$t := .25 \cdot \mathrm{in}$

$d_{cyl} := .9 \cdot \mathrm{in}$

$$A_{cyl} := \frac{D_{cyl}^2 - d_{cyl}^2}{4} \cdot \pi$$

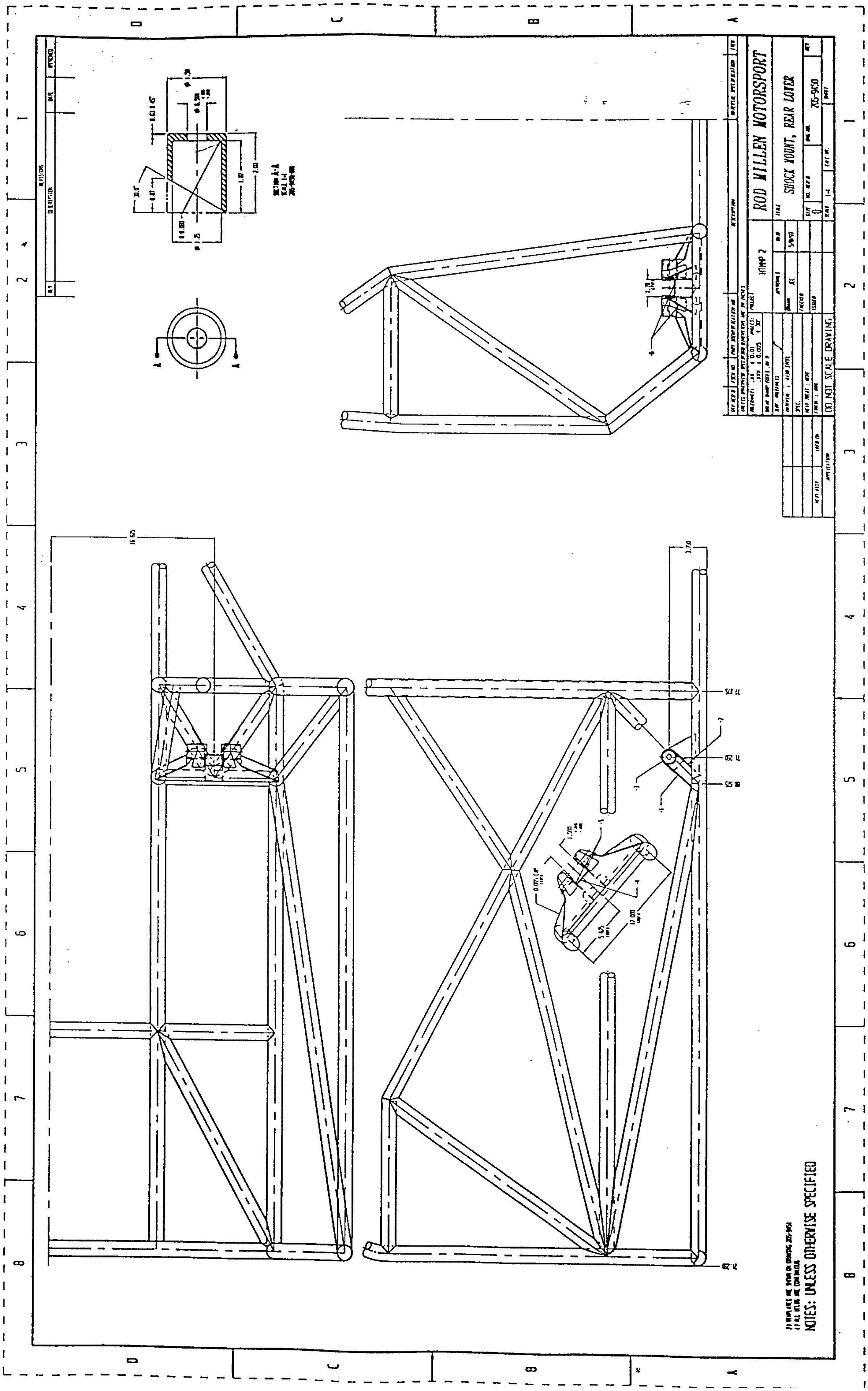
$$P := \frac{L}{A_{cyl}}$$

$P = 745.117 \cdot \mathrm{psi}$

$$\sigma := \frac{P \cdot D_{cyl}}{2 \cdot t}$$

$\sigma = 4.471 \cdot 10^3 \cdot \mathrm{psi}$

APPENDIX B



ROD MILLEN MOTORSPORT
SHOCK MOUNT, REAR LOWER
205-9450
SECTION A-A
DO NOT SCALE DRAWING
NOTES: UNLESS OTHERWISE SPECIFIED

APPENDIX C

Bench test results

Temperature: 70 deg F

Component condition: New

Lubrication: Mobil 1 15W50 synthetic oil, liberally applied to friction and floater plates

Instrumentation: Western Auto p/n H2837 beam-type torque wrench and Snap-on YA290 torque multiplier

Test results:

run #	shim thickness	static torque	dynamic torque
1	.115 inch	10 ft-lbf	10 ft-lbf
2	.104	160 ft-lbf	160 ft-lbf
3	.099	300 ft-lbf	280 ft-lbf
3	.092	400 ft-lbf	370 ft-lbf
3	.084	430 ft-lbf	415 ft-lbf
3	.077	500 ft-lbf	470 ft-lbf

note that torque measurements are +/- 10% due to difficulty in measuring

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ROCKETDYNE
SAFE ELECTROMECHANICAL BATTERIES (EMB) FOR ELECTRIC AND HYBRID ELECTRIC VEHICLE TECHNOLOGY FINAL REPORT

RD97-252

SAFE ELECTROMECHANICAL BATTERIES (EMB) FOR ELECTRIC AND HYBRID ELECTRIC VEHICLE TECHNOLOGY PROGRAM

Flywheel Containment System Validation

FINAL REPORT

August 1, 1997

Submitted by:

R. F. Sutton
Project Engineer

Approved by:

T. Lorier
Program Manager

Rocketdyne, a Division of
Boeing North American, Inc.

TABLE OF CONTENTS

Page

List of Figures

PROGRAM OVERVIEW

The task of the ElectroMechanical Battery System (EMB) project was to scale Rocketdyne's successfully demonstrated flywheel containment design to fit an existing EMB flywheel, sized for heavy-duty Hybrid Electric Vehicles (HEV) applications (1 kW-hr), and to verify the system safety on full-sized development test hardware. The Rocketdyne designed EMB system was also to be tested to obtain energy storage data and to validate the operation of the EMB at increments of speed up to the design speed of 24,000 rpm. Failure testing of the current EMB assembly was not practicable since inherent built-in system limits prevent exceeding the burst speed of the current flywheel fuse. Calculations have shown the burst speed (rim separation) should occur at about 49,300 rpm or at a rim energy of about 3.1 million ft-lbs. That energy level exceeds the safe operating level of the Rocketdyne test facilities, therefore an alternate approach was suggested to CALSTART and DARPA on October 2, 1996. The alternate approach was subsequently reviewed by DARPA and CALSTART with verbal approval given by Mr. Paul Helliker to the Rocketdyne Project Office on/about October 18,1996.

The alternate testing approach included the test-to-failure of another flywheel of the same general shape and materials as the current EMB system but having a thinner section at the fuse point of the high stress area of the rim such that failure of the outer rim will occur at 28,800 rpm or at a factor of 1.2 over the EMB operating design speed of 24,000 rpm. The rim storage energy of the test flywheel at 28,800 rpm was designed to be the same as for the current EMB flywheel at the point of rub with a containment ring designed to slow down the flywheel during an overspeed scenario and prevent flywheel rim failure.

PROGRAM SCHEDULE AND LOGIC

This 12-month project began on September 3, 1996 and ended on August 1, 1997 with the issuances of the final report. Figure 1 presents the project schedule with an outline of the overall tasks and the status of the tasks indicated by a darkened cross-section. Figure 2 presents the project's process flow logic which is a revision to the original program showing the discrete tasks to accomplish the goals of the project. The difference between the original program and the revision is that a secondary flywheel was used to test the rim burst scenario with the newly designed containment system. In addition, a parallel work path is shown to validate the current Rocketdyne EMB both operationally and to verify the electrical storage capabilities of the system.

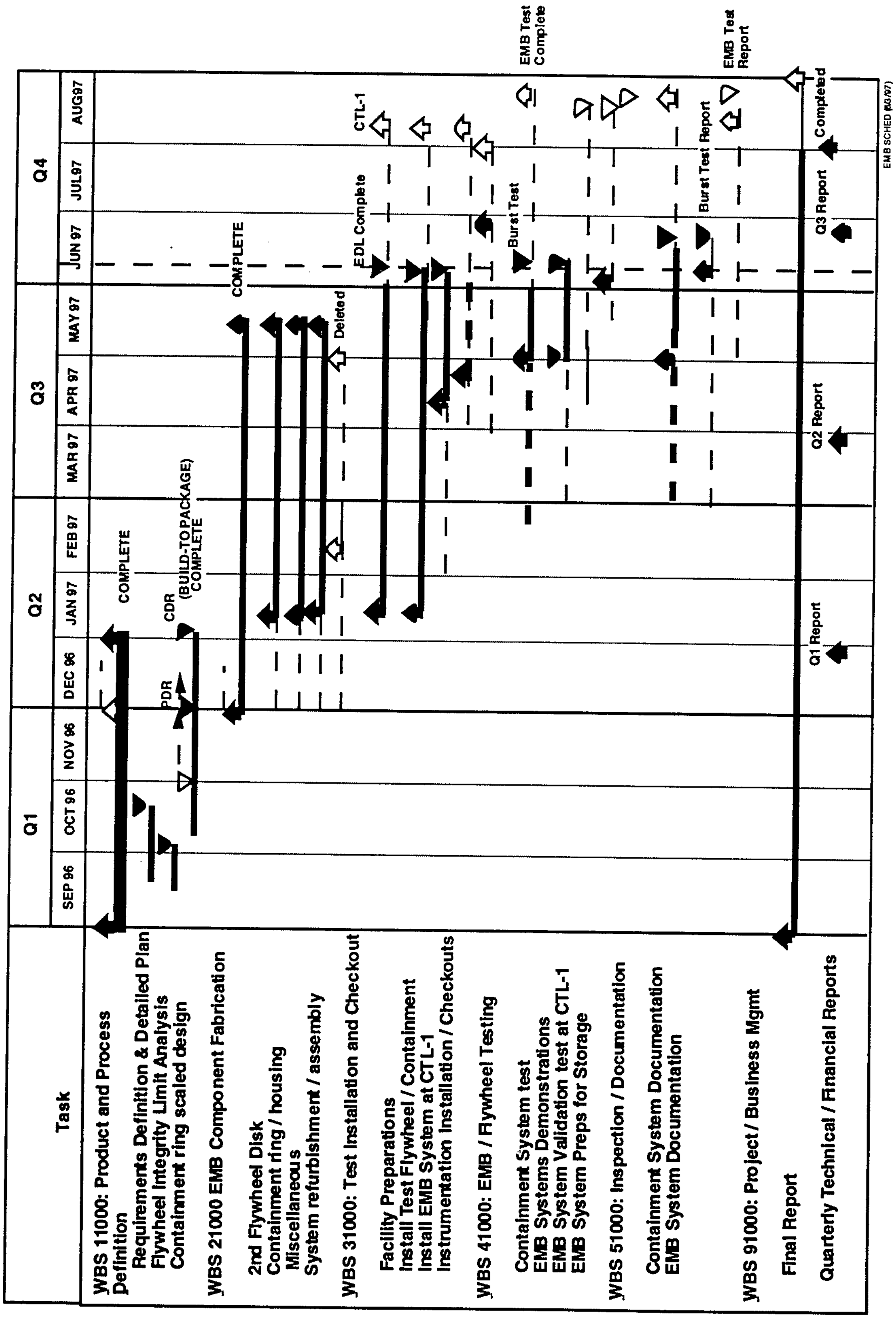
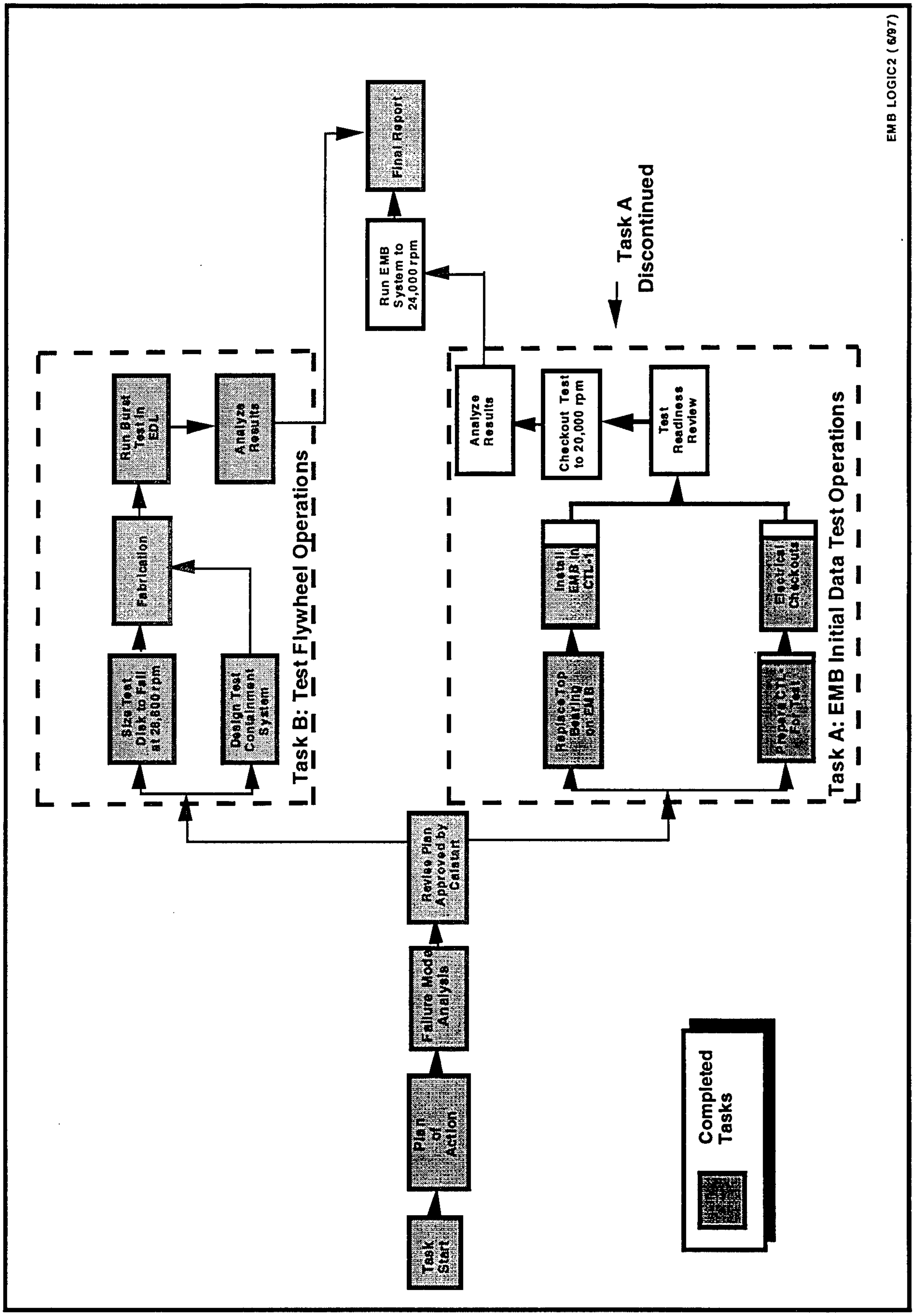


Figure 1 Program Schedule



Note: This revised plan was presented to DARPA and CALSTART on 10/2/96. Verbal Approval to proceed was given to Rocketdyne by Mr. Paul Helfiker on/about 10/18/96

Figure 2 Program Logic

WORK ACCOMPLISHED

An engineering Product and Process Plan of Action (PPPOA) document was issued to govern the program operations and design requirements. The concept of the flywheel containment system to be tested in the EDL spin pit progressed to the point that dimensional and failure dynamic analysis were completed. For the future retrofit containment design during operation (i.e. installed in a commercial bus or vehicle), the appropriate factor of safety will be used. A meeting of personnel with prior experience for this design problem reviewed the previous design base and analysis methods for the present project.

A rotordynamics review of the results of the last balance check made to the current assembled EMB rotor system indicated that it was balanced to the machine limits and was cleared for runup to the design speed of 24,000 rpm. The calculated rim burst speed for the existing EMB system flywheel, using annealed titanium (Ti6AL4V) properties, show the rim to separate (burst) at about 49,300 rpm or at a safety factor on energy of about 4:1. At this speed and rim weight (~9 lbs), the kinetic energy corresponds to about 3,100,000 ft-lbs. The Engineering Development Lab (EDL) was assigned the task of reviewing the safety factor of the assigned EDL spin pit for confirmation of its capability. The safety review showed that the spin pit has a safe energy rating of 2,700,000 ft-lbs. The overall energy of just the current designed EMB test flywheel assembly (~100 lbs) was too high for safely testing at 49,300 rpm in the EDL spin pit.

An alternate method which still met the project goals would be to spin a newly fabricated titanium (Ti6AL4V) 23-inch diameter flywheel with a necked down thickness at the high stress (fuse) area to burst or separate at 28,800 rpm. This burst speed is a 20% overspeed from the design speed of 24,000 rpm and will nearly duplicate the energy level (about 1.2 million ft-lbs) of the current EMB designed flywheel at the point of rim rub with a retrofited containment ring. In any follow-on effort, the existing flywheel design would have a containment ring sized for the rim energy at 28,800 rpm with a corresponding gap between the rim and containment ring to account for the growth and eventual rub of the flywheel to slow the wheel.

Detailed design effort of the attachment arbors to the test flywheel were made having the same fitup dimensions as the current EMB, spin test Teflon motion limiters (top and bottom) which also act as a disk catcher if the drive air turbine to flywheel arbor spindle breaks at the test flywheel rim burst. A Preliminary Design Review was held on the concept design, rim burst dynamics, and structural analysis of the system. The changes suggested at that meeting were incorporated into the design effort of the containment ring for tangential and radial impact forces along with sizing of the containment housing for the axial force component. Figure 3 shows the conceptual arrangement of the test flywheel and the containment ring and housing as it would be tested in the EDL spin pit.

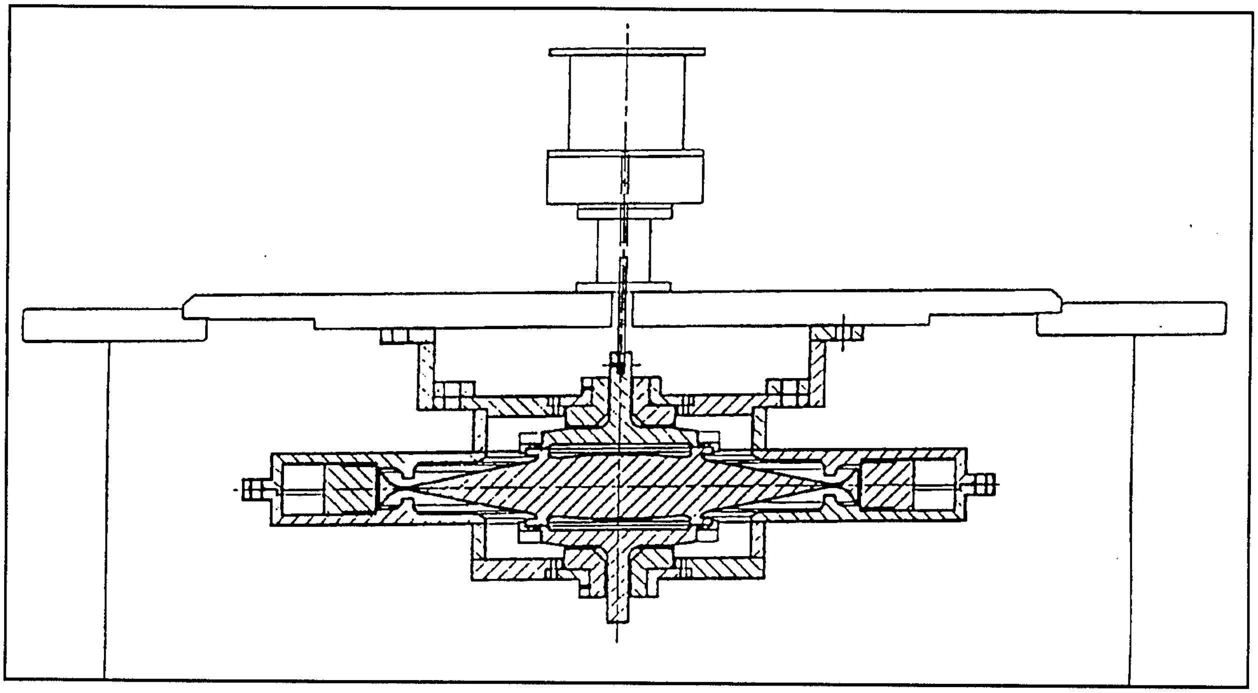


Figure 3. Burst Test Flywheel / Containment Assembly

Sub-contractors for the hardware fabrication were identified and three separate outside sub-contractors were selected for raw material supply or fabrication processes. One material supplier, Hurlen, located in Southern California, provided the majority of the housings raw material with most of the housings made from 304L Cres. The only other raw material ordered from Hurlen was the containment ring material which was Inconel 625. The arbor spin catchers with Teflon inserts were made by Finn Tool located in Chatsworth, California. Hales Engineering, located in Camarillo, California fabricated the majority of the flywheel containment system. The actual test flywheel and arbor attach fixtures were fabricated by Rocketdyne. The arbors and flywheel were fabricated from Titanium (Ti6AL4V) forgings.

All sub-components of the containment system were received in the Engineering Development Laboratory where some additional machining was accomplished to fit-up the entire assembly onto the spin pit lid. All parts to be installed into the spin pit and particularly those parts which were to be suspended from the lid were weighed. The actual spinning hardware (spin arbors, flywheel, and fasteners) weighed 106 lbs total. The containment assembly (mount assembly, upper and lower housings, containment ring, motion limiters with teflon inserts, and fasteners) weighed 753 lbs. The entire test assembly weighed 859 lbs. The spin pit lid was modified to accept the mount assembly by drilling and tapping eight, 3/4 inch diameter bolt holes. The final listing of the EMB test assembly parts along with the appropriate substitute fasteners is shown in Figure 4. Digital photography was accomplished to record the system hardware design. Figures 5 through 11 present the EMB Burst Test Hardware during the fit-up and installation and prior to the actual burst test.

A Test Operational Readiness Review (TORR) and Facility Safety Briefing was held on June 9, 1997. Specific areas addressed for the TORR were the project background, design and actual measurement information, test matrix and objectives, disposition of the hardware once the burst test was accomplished, the actual test plan which included instrumentation, automatic cutoff redlines (speed) and manual cutoff bluelines (spin turbine oil pressure, arbor shaft orbit, and spin pit vacuum level). No action item issues were left unresolved.

Preparations for the test included installing 4 equally spaced tangential strain gages onto the outer rim of the containment ring, a single thermocouple for monitoring the containment housing cavity temperature (a loss of vacuum will cause the temperature to rise due to disk windage heating), and two Bently proximitor gages to monitor the rotating assembly shaft orbit.

The flywheel burst test was accomplished on 6/13/97 at a burst speed of 22,903 rpm or about 20 percent lower than the predicted 28,800 rpm. The facility spin pit protection muffled the burst report but shortly after the recorded audible report, the Bently traces vanished from the oscilloscope screen indicating a loss of the instruments.

6/13/97

Tier 1	Tier 2	Tier 3	Tier 4	Description	#	Torque	Actual Installed Fastener	Torque
7R054251				Flywheel Dwg Tree	1			
	7R054251			Flywheel Test Installation	1			
		7R054253-1		Flywheel Test Assembly	1			
			MS9497-30(130Ksi)	Bolt, 0.75	8	280 +/- 15 ft-lbs	AN12-15 (120Ksi)	
			MS14183-C12	Washer, 0.75	8			
	7R054252			Test Assembly	1			
	7R054253			Rotating Assembly	1			
		7R054254-3		Rotor, Metallic	1			
		7R054255-3		Upper, Spin Arbor	1			
			MS9491-07	Bolt, 0.312	12	82 +/- 5 in-lbs	NAS1351-5-12(160Ksi)	
			MS9276-11	Lockwasher, 0.312	12		RD153-5006-0005 w/Locktite	
		7R054255-5		Lower, Spin Arbor	1			
			MS9491-07	Bolt, 0.312	12	82 +/- 5 in-lbs	NAS1351-5-12(160Ksi)	
			MS9276-11	Lockwasher, 0.312	12		RD153-5006-0005 w/Locktite	
		7R054256-3		Ring, Containment	1			
		7R054257-1		Mount Assembly	2			
			MS9497-10(130Ksi)	Bolt, 0.75	8	280 +/- 15 ft-lbs	AN12-11A (120Ksi)	
			MS14183-C12	Washer	8			
		7R054258-1		Upper Housing Assy	1			
			MS9494-17	Bolt, 0.50	24	100 +/- 5 ft-lbs	MS9494-17	
			MS14183-C8	Washer, 0.50	24		RD153-5006-0008	
		7R054258-11		Lower Housing Assy	1			
		7R054259-1		Upper Anti-Rotation Assy	1			
			MS9490-14	Bolt, 0.25	8	110 +/- 5 in-lbs	MS9490-14	
			MS14183-C4	Washer, 0.25	8		RD153-5004-1004	
			NAS1081C3012P	Set Screw, Nyloc	3	38 +/- 2 in-lbs		
		7R054259-11		Lower Anti-Rotation Assy	1			
			MS9490-14	Bolt, 0.25	8	110 +/- 5 in-lbs	MS9490-14	
			MS14183-C4	Washer, 0.25	8		RD153-5004-1004	
			NAS1081C3012P	Set Screw, Nyloc	3	38 +/- 2 in-lbs		

EMBPARTS.XLS

Figure 4 Flywheel Containment System Hardware Listing

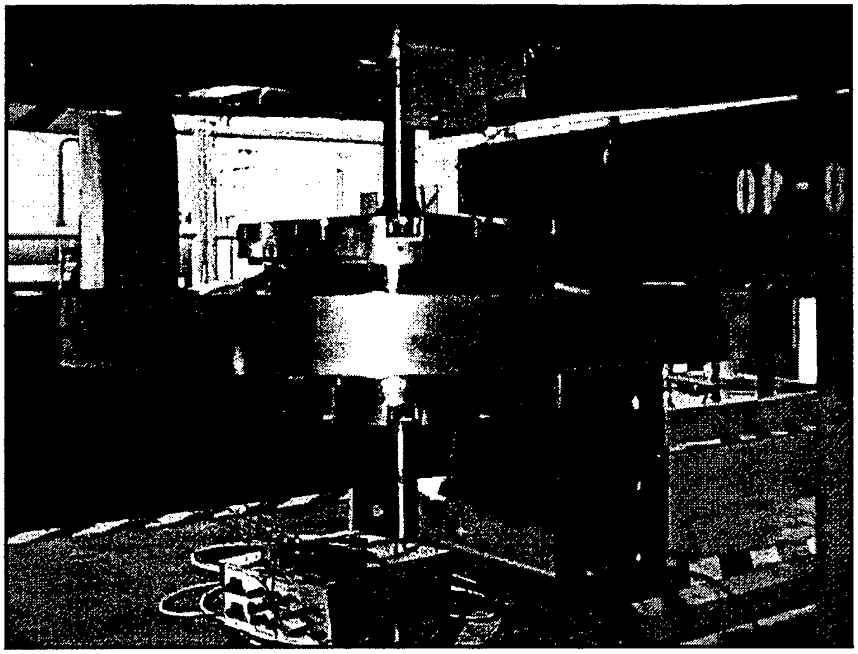


Figure 5 EMB Flywheel Assembly

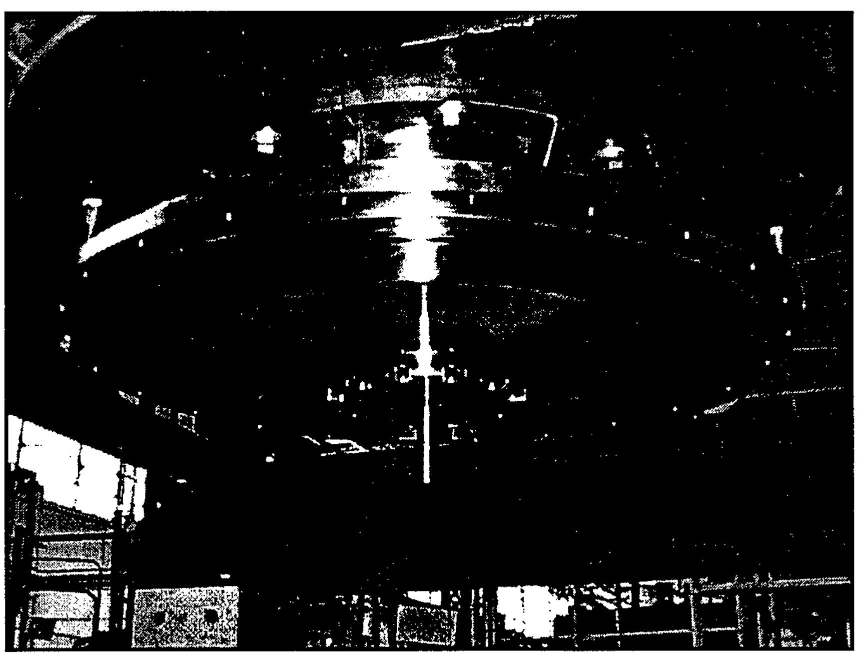


Figure 6 EMB Upper Housing and Flywheel Assembly

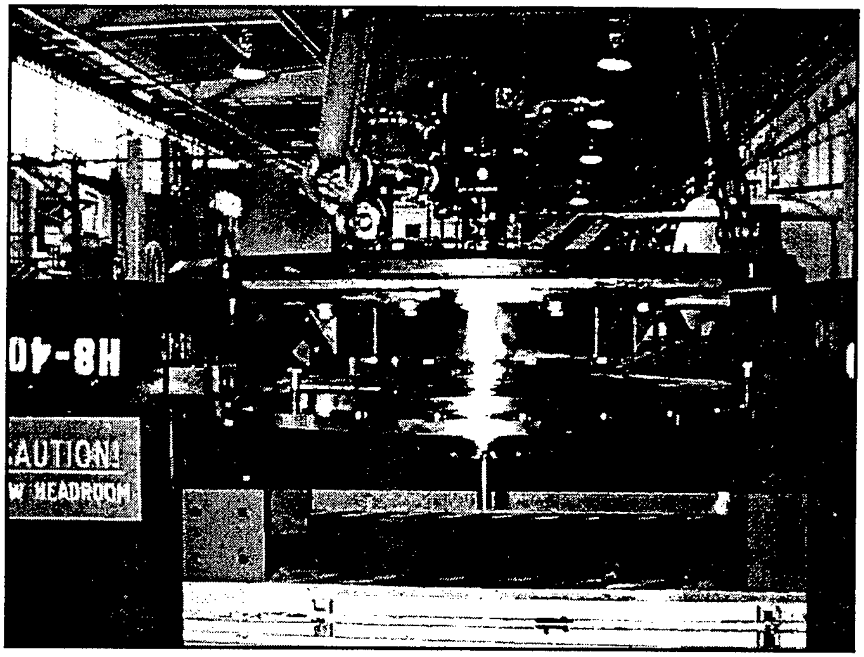


Figure 7 Spin Turbine EMB Housing Attachment

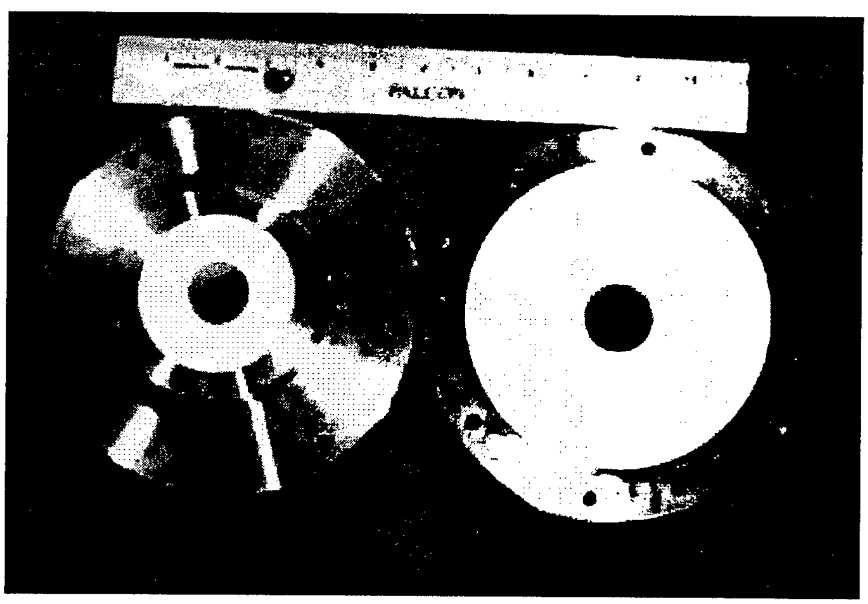


Figure 8 Flywheel / Containment Bushing Assembly

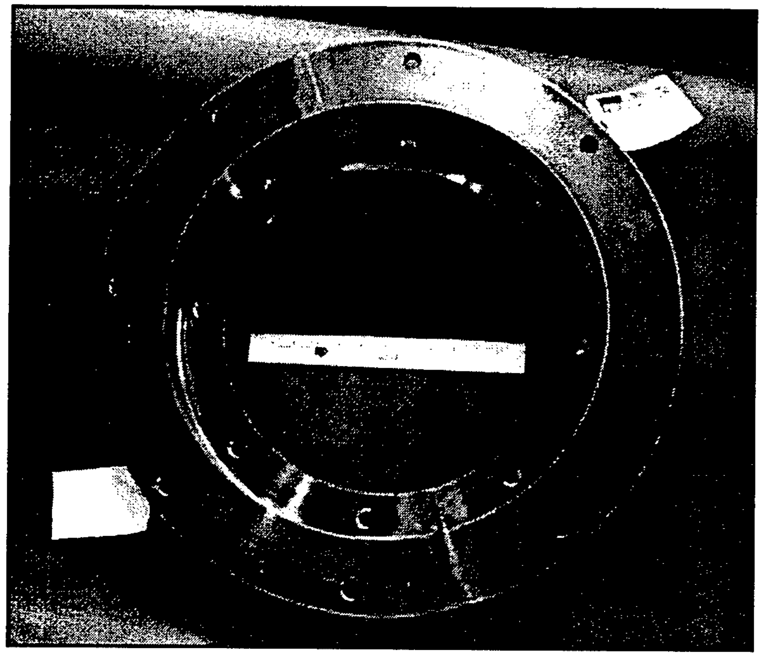


Figure 9 Flywheel / Containment Mount Assembly

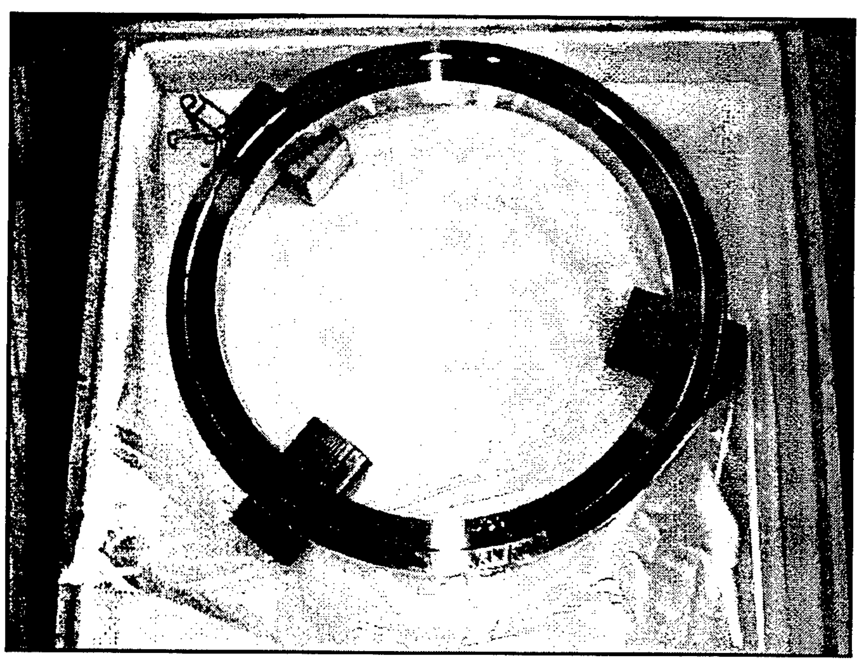


Figure 10 Flywheel Containment Ring

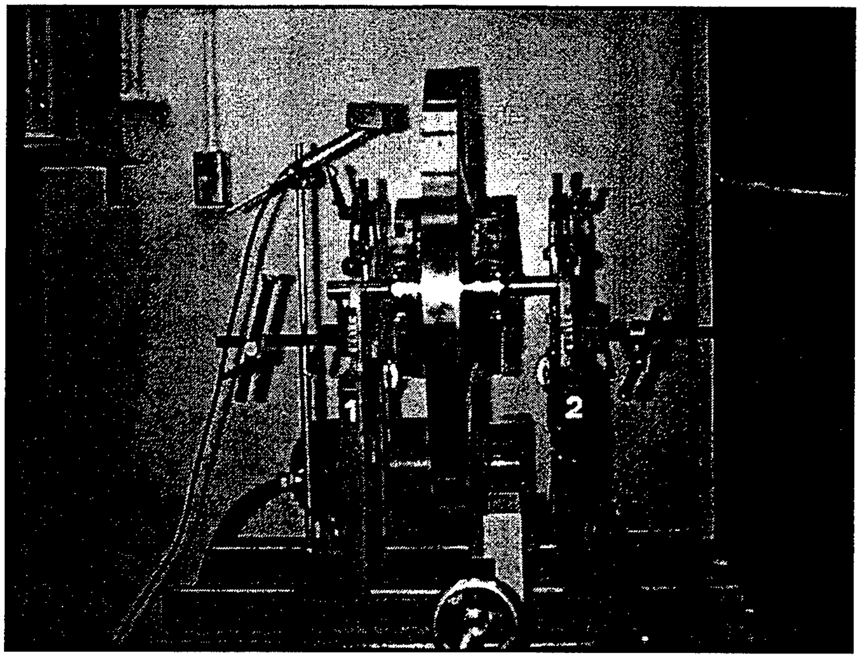


Figure 11 Flywheel / Arbor Balancing

The Electro Mechanical Battery (EMB) was developed for a destructive burst test at the EDL Canoga facility. The EMB is a titanium high speed rotating disk that uses angular momentum as the storage mechanism. The test was a controlled rim-fuse burst to demonstrate the EMB containment ring device developed by Rocketdyne. Several obvious preliminary observations can be made after disassembly of the housing assembly that contained the disk and containment ring.

The start of the test proceeded very smoothly and at the 20 rpm/sec predicted speed ramp calculation. The Bently orbit measured at the spin arbor shaft was very smooth with only about 0.004 inch orbit from 1000 rpm to the burst occurrence at 22,903 rpm where the Bently signals were lost due to both Bently's sensing tips being destroyed by contact by the top arbor shaft after rim separation and the attendant slight imbalance of the rotor due to separation of the wheel outer rim.

The flywheel containment housing assembly was removed from the spin pit with no damage noted to the exterior of the containment housings. The lower Teflon bushing was observed to have sustained a side load smoothly gouging out one quadrant of the Teflon but otherwise intact. The upper bushing likewise showed the same type of damage. The quill shaft was still intact indicating that the motion limiter Teflon bushings performed as designed. The top and bottom shaft motion limiters (Teflon), Figure 12, show the elliptical wear patterns caused by eccentric arbor shaft(s) motions at rim failure and thus prevented the failure of the turbine quill shaft by limiting the total shaft motions to less than the turbine built-in squeeze film damper(s) limits.

The containment housing cavity air temperature between the outer diameter of the containment ring and the housing joints indicated a rise from 80F to 480F within 2 seconds of the burst speed at 19 minutes into the test. Figure 13 presents the entire spin up speed versus time with the sudden drop in speed being a result of the rim failure. Figure 14 presents the record of the "south" location tangential strain gage (1 of 4) attached to the outer diameter of the containment ring and shows the impact of the flywheel rim at 1.2518 seconds. Figure 15 presents a high speed rendition of the flywheel speed versus time showing a minor drop in speed, probably due to rubbing and heat generation at about 1.2538 seconds followed by a noticeable drop in speed to about 22,200 rpm. It is estimated that the time between the impact incident and the slight drop in speed was 0.002 seconds with the flywheel making approximately 3/4 of a revolution. The remaining rotor (Figure 16), a weight of about 95 lbs, remained intact then agaom started increasing in speed due to the open spin turbine gas supply valve. The test engineer then cutoff the test by auto closure of the turbine spin gas supply. The rotor continued to spin freely after cutoff at a slow free wheeling decreasing speed of about -2.6 rpm/sec, until the gas speed braking action of the spin turbine stopped the rotor. If no gas braking had been applied, it is estimated that the remaining flywheel would have taken about 2.5 hours to come to a stop in the 10 torr atmosphere of the spin pit.

Figure 12 Teflon Motion Limiters Damage

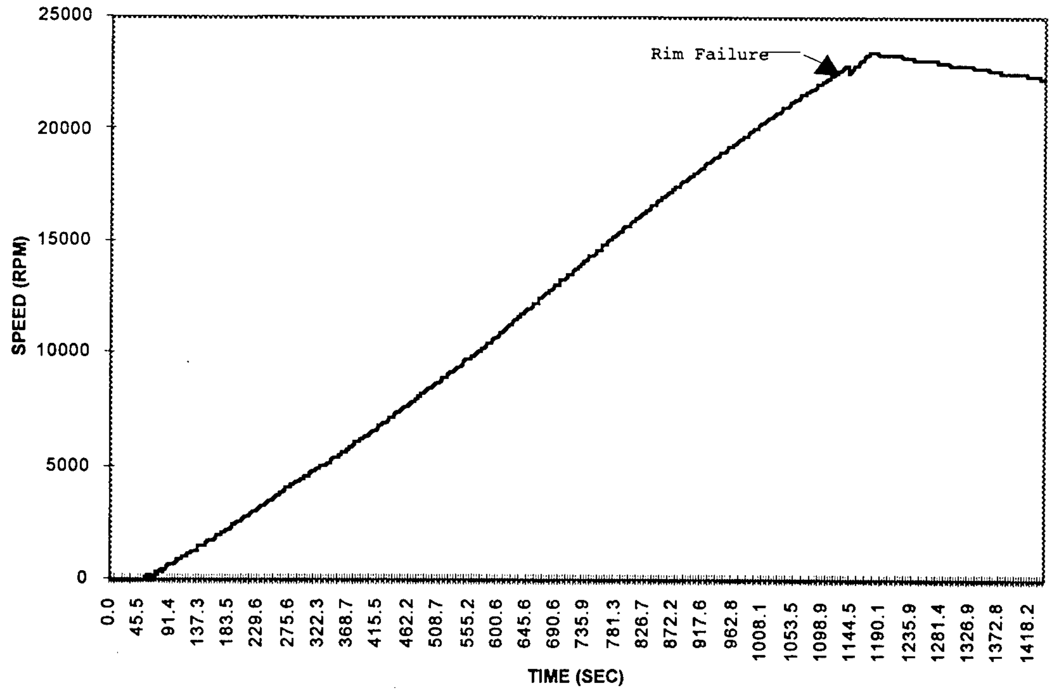


Figure 13 Flywheel Test Speed vs. Time

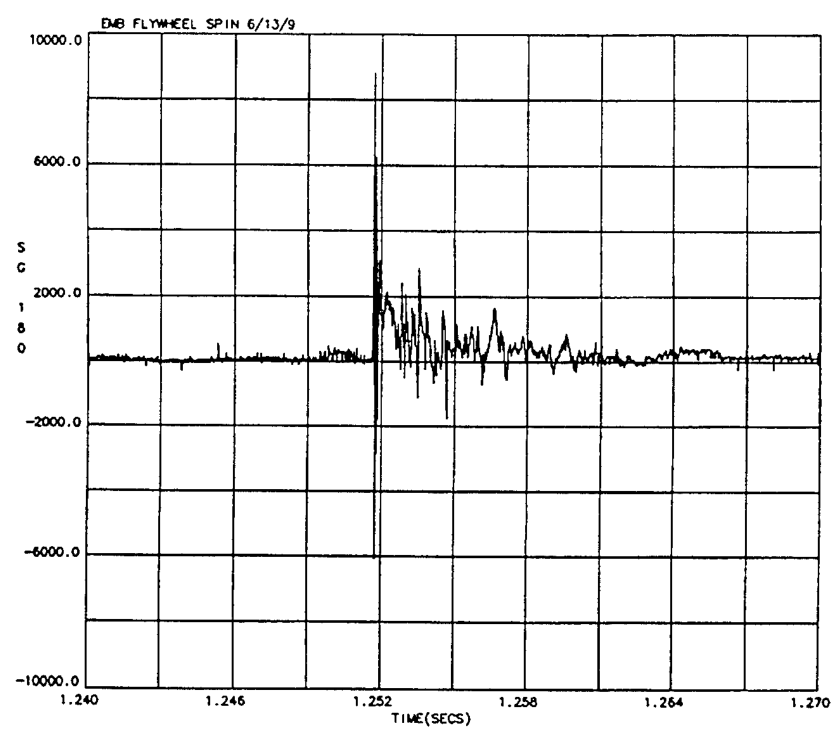


Figure 14 Ring Tangential Strain vs. Time

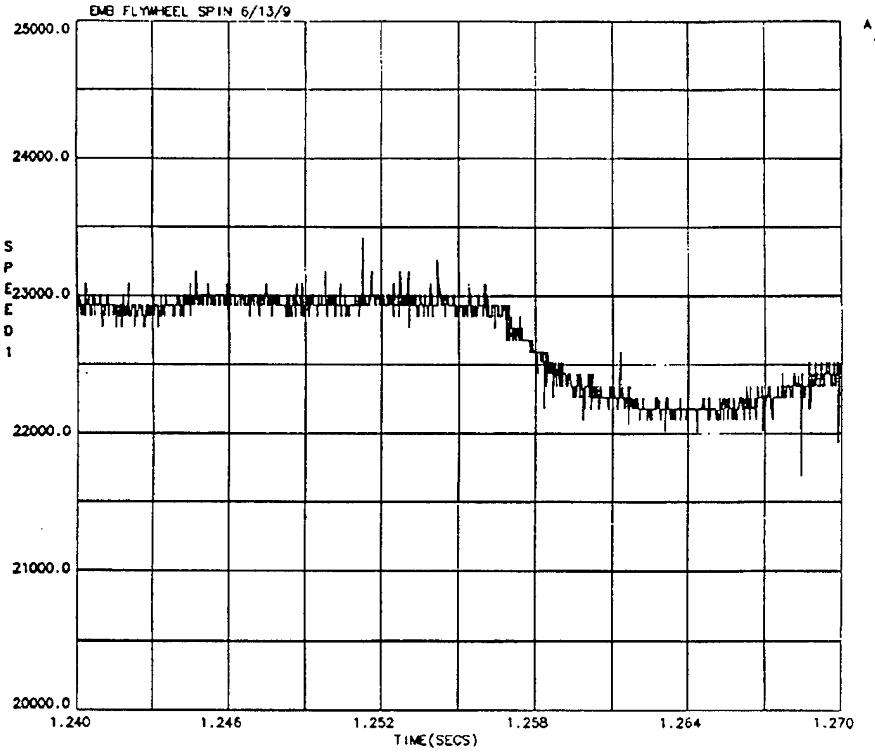


Figure 15 Flywheel Speed vs. Time at Failure

The initial effort to separate the upper from lower containment housing was unsuccessful. The flanges of both housings were separated by about 0.3 inch, enough to verify that the pilot fit was disengaged. The four strain gages were visually intact on the outer diameter of the containment ring, although from the initial installed strain gage clocking, the containment ring apparently rotated about 6 inches circumferentially. It is likely that the titanium flywheel rim at separation welded the containment ring (Inconel 625) to the upper and lower containment housings (304 CRES). In order to separate the two housings and obtain access to the failure hardware, a circumferential cut was made in the upper containment housing at the area just outboard of the shrapnel dam (Figure 17). Once that section was removed, the flywheel and separated rim was visible. From the post test / teardown visual inspections, the flywheel rim evidently separated at the fuse as planned (Figure 18) leaving the remaining portion of the flywheel intact and spinning freely. The remaining upper housing was then removed with some axial force to break the debris weldment. Figure 19 shows the upper housing with the Inconel 625 containment ring still fused to the 304L CRES housing. A close-up photo of the debris weldment is shown in Figure 20. The lower housing with the containment ring removed shows the melted titanium plasma in a ribbon like debris field (Figure 21). Marks in the pre-test dye colored area where the containment ring was installed and the location of the strain gages with respect to their installed positions show that the containment ring had rotated about 6 inches, probably during the flywheel rim hitting and rubbing the ring.

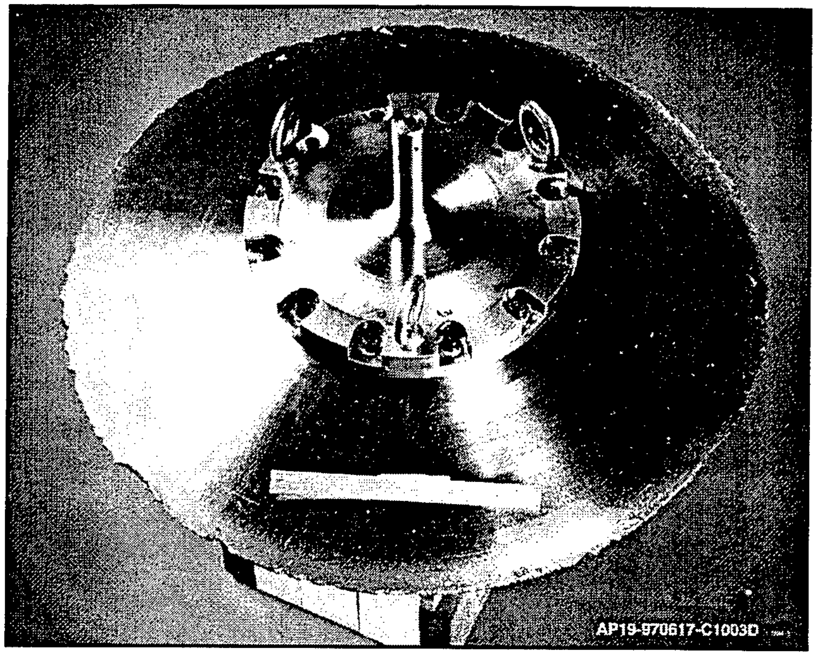


Figure 16 Flywheel Minus Ring

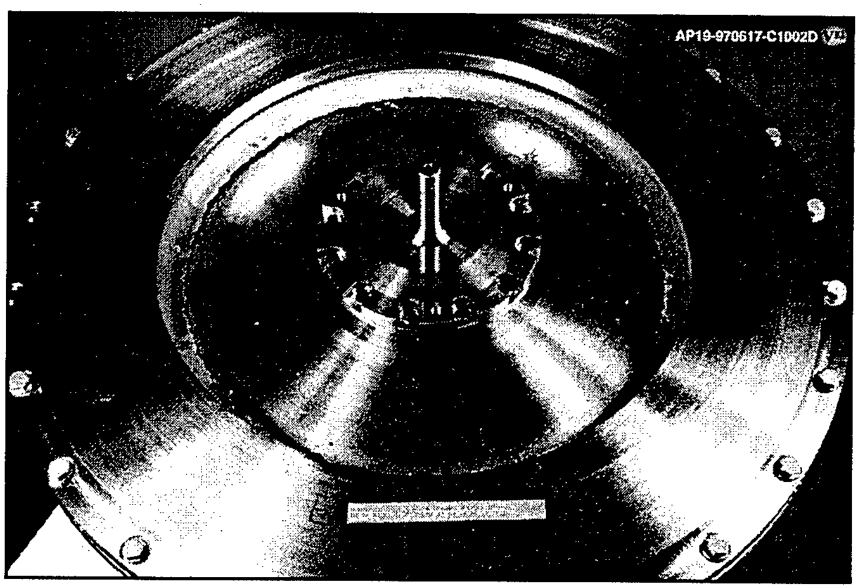


Figure 17 Upper Housing Cutout to Access Flywheel

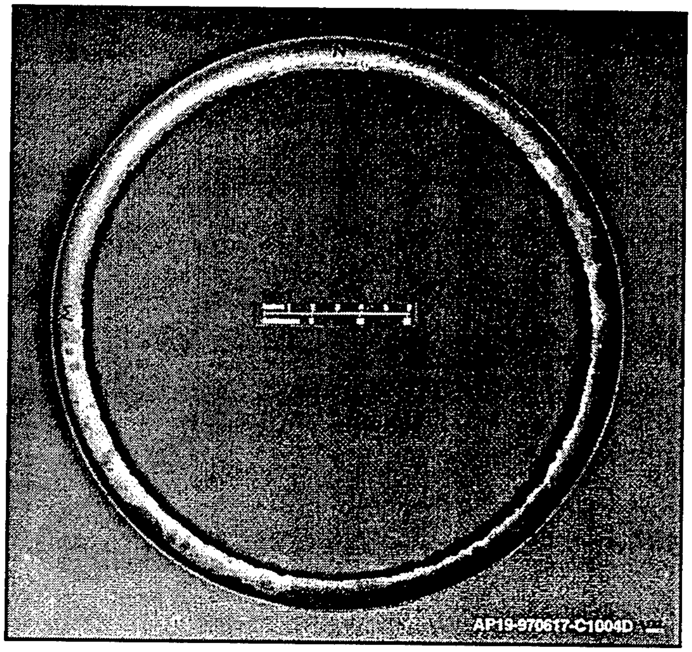


Figure 18 Flywheel Failed Rim

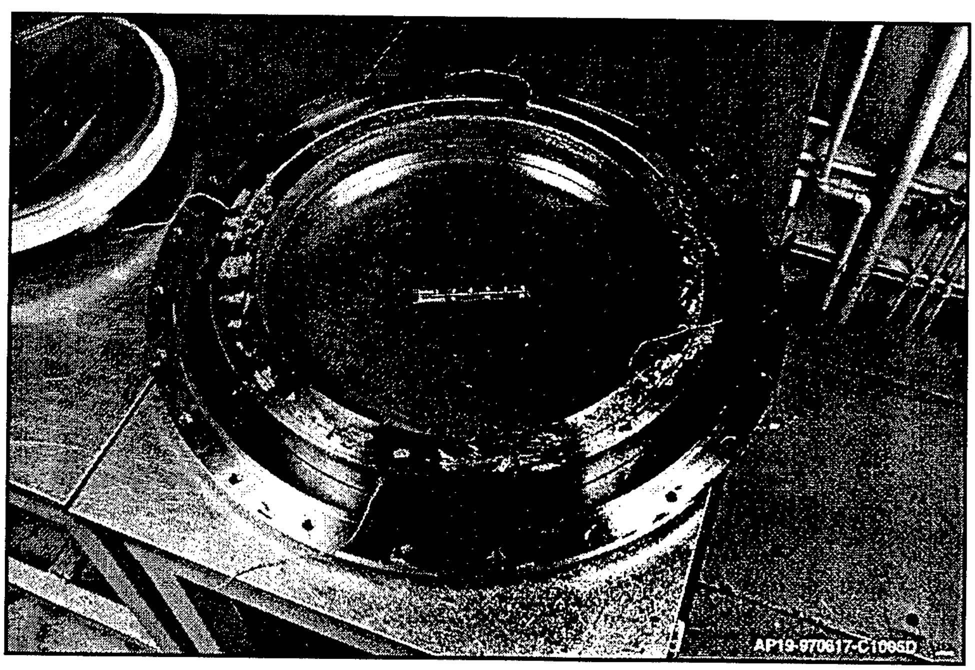


Figure 19 Upper Housing with Welded Containment Ring

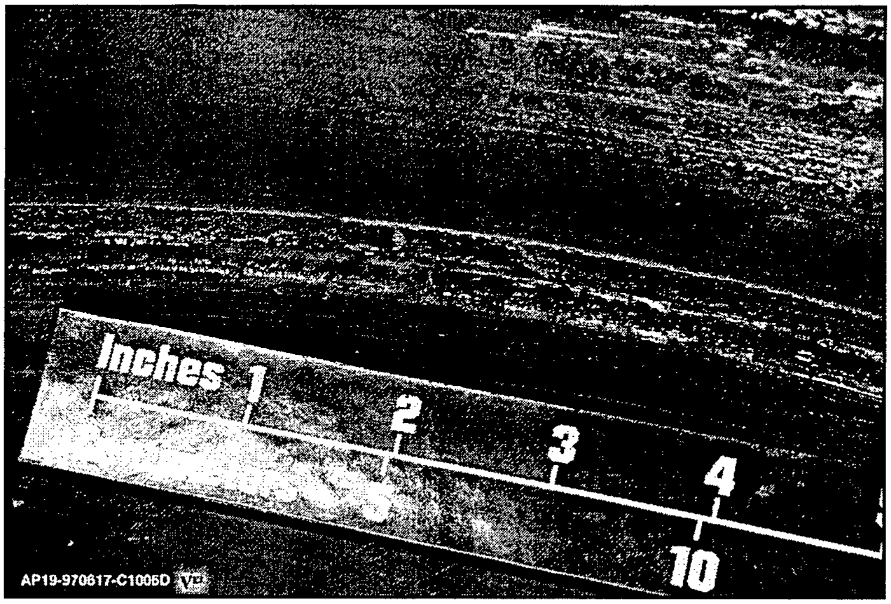


Figure 20 Closeup of Debris Weldment of Ring to Housing

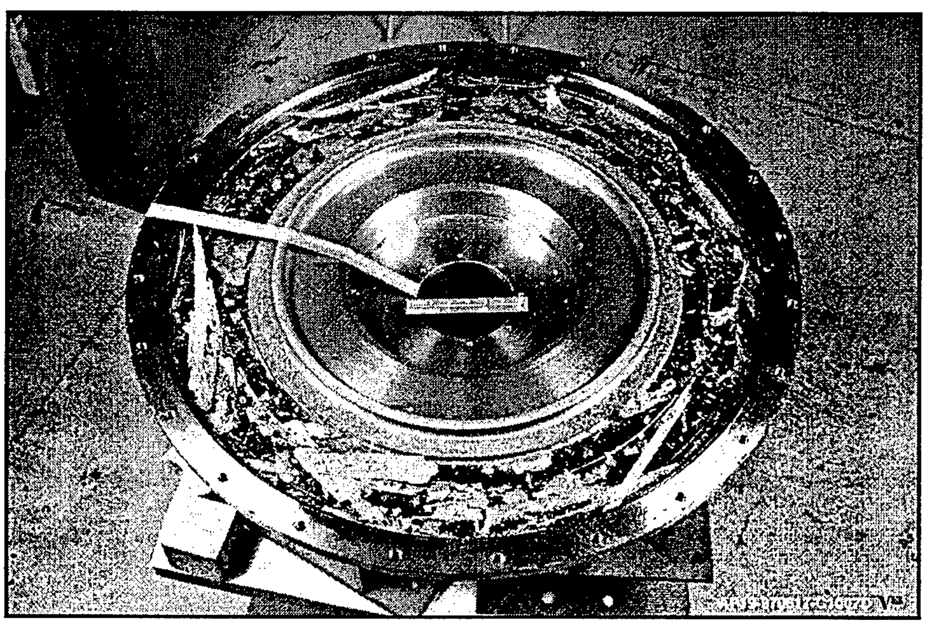


Figure 21 Lower Containment Housing with Melted Titanium Material

The hub-rim fracture zone is vary jagged and approximately a repeated 45° saw tooth. This fracture would indicate a maximum shear in the hub hoop direction. The fracture surface (without a detail metal fractography) appears to be without radial necking and/or classic cup-cone plastic behavior that would be expected for a radial biaxial overload. It would appear that there may have been an early rim-containment ring contact that torqued the rim against the rotating angular momentum of the hub and produced the observed shear fracture. Much of the fracture surface was destroyed by secondary failure contact particles generated from the damaged rim-ring.

Failure of the rim-hub was predicted to be under a uniform plastic strain in which the ductility (true stain at failure) was reached. The maximum predicted disk speed was 30.5K RPM if uniform uniaxial strain was achieved. Triaxiality factors were then used to predict failure as the uniform strain developed in the hub-rim fuse, which tend to become somewhat more brittle and reduce the predicted maximum attainable speed to 28.3K RPM. The major assumption is that uniform strain is present in any location 360 degrees around the hub-rim throughout the fuse. This assumption therefore assumes the maximum strain energy that the EMB can support under a perfect plasticity condition. A more realistic estimate would be 26K RPM with a little stability in the overload stress strain condition. A pessimistic speed predicted would be at the strain required at the onset of plasticity 21K RPM. The test failure was recorded at approximately 22.9K RPM. Due to the Ti6AL4V flat stress-strain curve, strain hardening effects as seen with most metals was not present in this test and therefore the test lacked stability from strain hardening that would have made plasticity more uniform. Nonuniform strains could have developed in the fuse that would force an out of balance loading and a premature contact with the rim-ring. This preliminary observation would be constant with the true strains predicted at 22.9K RPM failure.

Further possible contributory effects to failure are creep in a yield condition and triaxial effects in Ti6Al4V. Titanium that is highly stressed (yield and above) may have an accelerated creep rate. This would also add the to the instability and nonuniform plasticity. Also Ti6AL4V in a multi-axial stress field may have a more severe effect on ductility then was previously indicated.

The estimated energy level at rim failure was about 750,000 ft-lbs. No evidence of any parts exiting the containment system was observed. In fact, when access to the entire containment interior was attained, very little visual damage was observed from the arbor centerline to flywheel separation plane. The minimal damage evidence indicates that the shrapnel ricochet dam incorporated into the design performed as required.

During the latter stages of testing in the EDL laboratory to burst the test disk, a low level of effort was also accomplished at the CTL-1 test facility to prepare for the testing of the complete

EMB system. Once the data reduction was completed on the failed test disk, the remaining funds did not support the task needed to finish the installation, checkout, and the final data test of the EMB to the normal operating speed of 24,000 rpm. The project was stopped and all remaining funding was used in preparation of this final report.

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ENGINE CORPORATION OF AMERICA
FINAL REPORT

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Development and Demonstration of an Advanced Heavy Fuel Injector for UAV and HEV Applications
Phase I

Final Report
September 30, 1997

Prepared by:
Dr. Marius A. Paul, Principal Investigator

Prepared Under Cooperative Agreement Number:

MDA972-95-2-0011
Modification No.: P009
ARPA Order No.: B878/18
Effective Date: 4/15/97

and
Program Participant Agreement
Between CALSTART, Inc, and
Engine Corporation of America
Contract Dated April 15, 1997

EXECUTIVE SUMMARY

In this report, ECA provides the results of its study, calculations and test results for its two-stroke opposed piston engine and fuel injection system. This Executive Summary describes, by task, the work that ECA performed and the conclusions reached under Phase I of the above - referenced this contract.

Task 1.1 Overall Engine Design

Overall engine designs were produced for ECA's 1.0 liter opposed piston engine and the 0.5 liter "half-engine" variant. These designs were made in such a manner as to support their use as engine modules for the creation of a family of engines having multiple cylinders and multiple military and commercial applications.

In support of this task and going well beyond the Statement of Work and the requirements of this contract, ECA fabricated plastic 1:1 scale models of all major engine components – block, crankcase, crankshafts, connecting rods, cylinder liner, piston crown, piston head, piston skirt, and rotary valves. These components were fabricated using state-of-the-art stereo lithographic methods, which are also described in the body of the report. All of these components were furnished to FEV in support of their analytic work and to perform flow bench tests on these parts.

Task 1.2 Engine Thermal Cycle Analysis

ECA performed extensive calculations on the intrinsic and extrinsic variables for the 1.0 liter and 0.5 liter engines. Detailed attention was paid to the expected duty cycle for the endurance UAV (Predator) application. ECA presents herein numerous charts and graphs summarizing the results of these calculations.

For a duty cycle typical of an endurance UAV, and in comparison to the Rotax 912 engine, which is currently used in the Predator, ECA's TECE 1.0 engine can cruise at 125 knots compared to 95 knots for the Rotax, can reach a target at 500 nautical miles in only 4.0 hours compared to 5.3, and can loiter over the target for 67.6 hours compared to only 25.4 for the Rotax. All other comparisons to existing engines favor the ECA design.

Task 1.3 Coordination of the Analytical Effort

ECA has provided FEV with all of the information, drawings, calculations, and parts requested and/or needed by FEV. The final meeting between ECA and FEV will be held on October 1.

Task 2.1 Overall Fuel Injection Design

ECA has completed the assembly and detailed design drawings for the fuel injection system. This injection system features the shortest possible injection time and the highest possible pressure, to achieve the best thermal efficiency and lowest emissions. The system also features electronic control of the start and end points of the injection, providing complete flexibility, and multiple pilot and main injections for the achievement of a lean homogeneous mixture and minimal emissions. Finally, this injection system features a triangular injection profile, the pressure of which is a direct function of the actual pressure in the cylinder, thereby assuring superior mixing and penetration throughout the entire injection process.

The design of this injection system is such that no mechanical transmission or driving system is needed, the energy not completely used for the pressurization of the fuel is returned to the engine during the expansion stroke, and the injection tip design assures a conical vortex injection spray to achieve a homogeneous lean mixture for combustion.

Going beyond the design activity called for in ECA's Statement of Work, ECA has actually built and tested (on the injector test bench) the unit injector designed under this contract. The injection of fuel, which was demonstrated in open air where it is visible, achieved a very fine degree of atomization.

Task 2.2 Fuel Injection Options Assessment

ECA evaluated only the highest technology fuel injection systems available on the market today – the Bosch Electronically–Controlled Unit Injector and the Caterpillar/Navistar Hydraulic Electronic Unit Injection ("HEUI") fuel system.

The Bosch System is capable of reaching injection pressures of 30,000 psi, but even these pressures may not be high enough to successfully operate ECA's engine at its peak pressure capability of 4500 – 5000 psi. In addition, the Bosch injector requires a mechanical driving system, which would greatly complicate the engine design and add unnecessary cost. This mechanical system cannot feature the control and flexibility offered by ECA's design.

The HEUI system is also unacceptable, but for different reasons. First, the pressures attainable with the HEUI system are limited to approximately 1500 bar, which is even less than the Bosch system offers. The HEUI system is also subject to multiple-chamber Helmholtz pressure wave instability.

However, the most important deficiency present in the HEUI system is the "injection rate trace", which demonstrates that the last 50% of the injection is a slow decaying pressure drop, including a residual very low pressure "step" injection. This characteristic negatively affects fuel atomization and combustion quality. At the higher operating pressures of ECA's engine, these characteristics would be completely unacceptable.

Task 2.3 Coordinated Fuel Injection Review with FEV

This meeting will be held on October 1, 1997.

TASK 1: THERMODYNAMIC CYCLE ANALYSIS'

TASK 1.1 OVERALL ENGINE DESIGN.

ENGINE CORPORATION OF AMERICA ACCOMPLISHED THE OBJECTIVES OF THE TASK1.1 PRODUCING THE OVER ALL DESIGNS FOR THE 1.0 LITER AND THE 0.5 LITER ENGINES, CONSIDERING EACH MONOCYLINDER THE MODULE MEMBER OF A TWO COMPLETE FAMILIES OF MODULIZED ENGINES, WITH MULTIPLE CYLINDERS AND MULTIPLE MILITARY AND COMMERCIAL APPLICATIONS.

THE 0.5 LITER ENGINES ARE ABLE TO BE THE COMMON BASE FOR TWO AND FOUR STROKE ENGINES ,HAVING THE EXCEPTIONAL AND UNIC CAPABILITY OF CONVERATBILITY FROM EACH OPERATING REGIMES AND CYCLES, DEPENDING ON THE VARIABLE POWER AND LOADS NECESSITIES.

THERMO ELECTRIC TURBO COMPOUND

THE BASIC CONCEPT OF THE THERMOELECTRIC TURBO COMPOUND ,ULTRA HIGH PRESSURE , ULTRA HIGH EFFICIENT,ENGINE AND CONCEPT, CAPABLE TO REACH THE ABSOLUTE MAXIMUM THERMODYNAMIC EFFICIENCY IN THE FIELD OF 60-80 % EFFICIENCY, ASSOCIATED WITH MULTI FUEL CAPABILITY , ULTRA LOW EMISSION , AND ULTRA LOW SMOKE AND INFRA RED SIGNATURE ,IS THE IDEAL ANSWER TO THE DARPA /DARO MISSIONS.

THE COMBINED MISSIONS AND COMBINED SPONSORSHIP OF DARPA AND DARO IS THE LOGIC AND PERFECT CONTINUATION OF THE PREVIOUS CONTRACT SPONSORED BY DARPA FOR THE HLTRA HIGH PRESSURE . MONOCYLINDER 1.5 LITER ENGINE , WHICH DEMONSTRATED THE HIGHEST COMBUSTION PRESSURE CAPABILITY AND

CORRESPONDENTLY THE HIGHEST THERMODYNAMIC EFFICIENCY CAPABILITY, IN ALL THE HISTORY OF THERMAL ENGINES.

THE THERMOELECTRIC COMPOUND CONCEPT APPLIED AND ASSOCIATED WITH THE HIGHEST PRESSURE COMBUSTION CYCLE , SPECIFIC FOR THE DIESEL CYCLE IS THE PERFECT APPLICATION OF THE TOTAL EXPANSION RATIO SPECIFIC FOR THE BRAYTON CYCLE.

THESE COMBINED CYCLES WORKING AT THE HIGHEST PEACK PRESSURE RATIOS 300/1 – 350/1, ARE ABLE TO WORK AT THE HIGHEST COMPRESSION RATIOS OF 30-37 WHICH IS OBVIOUS THE CONDITION FOR THE HIGHEST THERMAL EFFICIENCY NEAR/OVER 80% , AND / OR TO BE SUPERCHARGED AT ULTRA HIGH LEVEL OF MORE THAN 10 /1 PRESSURE RATIOS, WHICH IS THE FUNDAMENTAL CONDITIONS TO ACHIEVE THE HIGHEST POWER DENSITY, NEAR /OVER 500 HP /LITER.

ULTRA HIGH PRESSURE ELECTRO HYDRAULIC SELF INJECTION SYSTEM

THE ULTRA HIGH PRESSURE 40,000 –60,000 PSI ELECTRO HYDRAULIC INJECTION SYSTEM , CAPABLE TO WORK ON THE SELF INJECTION MODE OR COMMON RAIL MODE OF OPERATION ,IS THE OBVIOUS **ABSOLUTE CONDITION** FOR ACHIEVING THE PERFECT MATCH WITH THE **HIGHEST COMBUSTION PRESSURE** CAPABLE TO BE DEVELOPED IN THE ECA ENGINES.

THE GENERALITY AND FLEXIBLITY OF THE ECA ELECTRO HYDRAYLIC SELF/ OR COMMON RAIL INJECTION SYSTEM IS THE **IMMEDIATE SPIN- OF TECHNOLOGY READY** TO BE CUSTOMIZED FOR LARGE AND GENERAL MARKET EXISTING ENGINES APPLICATION.

THE MULTIPLE SECVENTIAL INJECTION SYSTEM , CAPABLE FOR MULTIPLE PILOT-MAIN INJECTIONS, WITH ULTRA HIGH SPEED VORTEX FUEL SPRAY ACCELERATION IS THE FUNDAMENTAL CONDITION TO ACHIEVE LEAN AND ULTRA LEAN MIXTURES, OF HOMOGENEOUSE FINAL COMBUSTION ULTRA CLEAN COMBUSTION .

THE MULTIPLE INJECTORS 1,2,3,4, INTEGRATED IN THE TURBO COMBUSTION CHAMBER, ARE ABLE TO GENERATE A PERFECT HOMOGENEOUSE AIR /FUEL MIXTURE AND THE CLEANEST COMBUSTION PROCESS WITH ANY KIND OF LIQUID FUELS .

THE MULTIPLE INJECTORS CAN CONSERV THE QUALITY OF ATOMIZATION , BY SECVENTIAL OPERATIONS AT FULL AND PART LOADS , BY SIMPLE ACTIVATION OR DESACTIVATION OF THE INJECTORS FUNCTION OF THE LOADS.

CONSTANT PRESSURE COMBUSTION SYSTEM

THE THERMOELECTRIC COMPOUND ECA ENGINE CONCEPT, IS ABLE TO CONSERV AT ALL LOADS AND ROTATIONS A CONSTANT PRESSURE SUPER CHARGING LEVEL , REZULTING A CONSTANT PRESSURE COMPRESSION PRESSURE AND AUTOMATIC CONSERVATION OF THE COMBUSTION PRESSURE, IS THE FUNDAMENTAL CONDITION FOR CONSTANT THERMAL EFFICIENCY AND BY DEFINITION A CONSTANT FLAT SPECIFIC FUEL CONSUMPTION, IN ALL THE PRACTICAL FIELD OF OPERATIONS.

TOTAL INTAKE TOTAL EXHAUST

THE TOTAL INTAKE AND EXHAUST CONCEPT FOR MAXIMIZATION OF THE BREATHING CAPACITY OF THE ENGINE CAN ACHIEVE AN **ABSOLUTE MAXIMUM** BY THE **EQUALITY OF THE INTAKE AREA WITH THE AREA OF THE PISTION**. THIS CAPABILITY IS SOLVING THE UNIVERSAL PROBLEM OF INSUFICIENT BREATHING CAPABILITY OF ALL EXISTING ENGINES. THE TOTAL INTAKE AND TOTAL EXHAUST CONCEPT IS USING THE SAME PORTS SUCCESSIVELLY FOR INTAKE AND EXHAUST WHICH IS ELIMINATING THE BIGGEST BARIER OF HIGH THERMAL STRESS FOR THE ENGINES WITH SEPARATE INTAKE AND EXHAUST PORTS OR VALVES, AND IS ALEVIATING THE BARIER FOR ACHIEVING HIGH AND ULTRA HIGH SPEED OF OPRATIONS.

BY THE INDEPENDENT ELECTRIC DRIEVEN OF THE TURBO COMPRESSOR AND THE INDEPENDENT TURBINE ELECTRIC TURBO GENERATOR, THE PERFECT THERMOELECTRIC COMPOUND CONCEPT AND SYSTEM IS THE COMPLETE SOLUTION AND GUARANTOR OF

THE ELIMINATION OF MANY FUNDAMENTAL PROBLEMS WHICH SUFFER THE MODERN ENGINES.

ELIMINATION OF THE " TURBO LAG EFFECT"

SPECIFICALLY FOR MILITARY ENGINES THE INTENS SMOKE GENERATION AT ALL ACCELERATIONS IS THE WORST DFFECT OF DETECTABILITY, AND FOR THE COMMERCIAL ENGINES BIG EMISSION LEVEL IN SPECIAL IN URBAN OPERATIONS OF THE TURBOCHARGED ENGINES , PLAGUED BY THE TURBO LAG EFFECT (DEFECT) , GENERATING REACH MIXTURE COMBUSTION IN THE TIME OF "LAG " LOW PRESSURE SUPERCHARGING TIME, IS THE CONDITION OF **NONE ACCEPTABILITY** OF DIESEL ENGINES, IN URBAN TRANSPORTATION.

THE ELIMINATION OF THE TURBO LAG EFFECT IS GIEVING TO THE VECHICLES AN INSTANT ACCELERATION CAPABILITY , WHICH IS AN ESSENTIAL MILITATARY QUALITY OF MANEOVRABILITY, ON THE BATTLE FIELD.

HYBRID PROPULSION SYSTEM

FOR HYBRID PROPULSION SYSTEM THE ECA THERMO ELECTRIC COMPOUND SYSTEM IS THE MOST EFFICIENT MOD OF PROPULSION BECAUSE CAN REDUCE TO THE MINIMUM LEVEL THE BATERY DIMENSIONS AND FOR SOME APPLICATION THE TOTAL ELIMINATION OF THE BATERIES. ACTUALLY THE BATTERY TECHNOLOGY IS THE BIGGEST ECONOMIC ENEMY OF THE HYBRID PROPULSION IN THE REAL ECONOMYC WORLD.

ZERO INERTIA FORCESS AND MOMENTUM , PERFECT BALANCED ENGINE

THE OPPOSED PISTONS ENGINE PROVIDED WITH TWO COUNTER ROTATING MECHANISM, IS THE MATHEMATICAL PERFECT BALANCED MECHANISM FOR TRANSFORMATION OF THE LINEAR PISTON MOVEMENT IN ROTATIONS, WITH ZERO VIBRATIONS. FOR MILITARY APPLICATIONS ON AIRCRAFT PROPULSION AND SUBMARINE APPLICATIONS IS THE ABSOLUTE IDEAL TECHNICAL SOLUTION. THE UAV APPLICATION

FOR ULTRA LIGHT AIR VECHICLES THE ABSENCE OF VIBRATION IS AN ESSENTIAL INVALUABLE CARACTERISTIC.

THE ELIMINATIONS OF THE SIDE FORCESS BETWEEN PISTON AND CYLINDER LINER AND THE ELIMINATION OR REDUCTION OF THE GAS PENETRATIONS BEHIND THE PISTON RINGS ASSOCIATED WITH THE ELIMINATIONS OF THE VALVES MACHANISM , IS THE CRUCIAL SOLUTION FOR ACHIEVING ULTRA HIGH PRESSURE COMBUSTIONS.

ULTRA LIGHT STRUCTURE

THE CORE STRUCTURE OF THE ECA ENGINE ,IS BASED ON A SANDWICH ASSOCIATION OF THE CENTRAL CYLINDER BLOC , SIDED ON BOTH EXTREMITIES BY THE CRANK CASES , BOLTED LONGITUDINALLY FROM ONE SIDE TO THE OPPOSITE SIDE, BY THROUGH LONG BOLTS. THE ENTIRE STRUCTURE IS ASSAMBLED PRECOMPRESSED, AND RELAXED WHEN THE COMBUSTION PRESSURE IS ACTING ON BOTH AXIAL SIDE,

ONLY THE LONG BOLTS ARE PERMANENT STRESSED AT THE NORMAL LEVEL OF CAPABILITY.

THE DIRECT REZULT IS THE LIGHTEST STRESS AND OBVIOUSE THE LIGHTEST STRUCTURE OF THE ENTIRE ENGINE. THIS IS A PERFECT STRUCTURE FOR ALL VECHICULAR APPLICATIONS , AND IN SPECIAL FOR AIR CRAFT.

THE SUPREEME QUALITY IS THE SUPREEME SIMPLICITY WITH THE LOWEST NUMBER OF PARTS AND LOWEST SPECIFIC WEIGHT (1 LB /HP). THE FINAL REZULT IS THE LOWEST SPECIFIC PRICE PER HP. AND CORRESPONDENTLY THE LOWEST LOGISTIC AND MAINTAINENCE COST.

TOTAL THERMAL ENERGY CYCLE

THE THERMAL ENERGY GENERATED IN THE ENGINE CYCLE IS DISTRIBUTED IN FOUR MAJOR COMPONENTS , EFFECTIVE ENERGY AVAILABLE FOR PRODUCING EFFECTIVE POWER, EXHAUST ENERGY , COOLING ENERGY , AND MECHANICAL FRICTION.

THE ECA ULTRA HIGH PRESSURE CYCLE , THE THERMOELECTRIC COMPOUNDING SYSTEM , AND THE GENERAL REDUCTION OF THE MECHANICAL FRICTIONS BY THE COUNTER ROTATING MECHANISM , ARE COMPOUNDING THEIR EFFECTS FOR MAXIMIZATION OF THE EFFECTIVE ENERGY AVAILABLE FOR THE EFFECTIVE POWER

THE COOLING ENERGY, CONVENTIONALLY ELIMINATED FROM THE CYCLE BY THE CONVENTIONAL COOLING SYSTEM IS AN ABSOLUTE ENERGY TOTAL WAIST, AND AN ADDITIONAL COMPLEXITY , WEIGHT, AND FINALLY ADDITIONAL COST .

THE ECA TOTAL THERMAL CYCLE IS ELIMINATING THE COOLING SYSTEM BY A NEW CONCEPT OF **ADIABATIC REGENERATION , ELIMINATING THE MAJOR PROBLEMS ASSOCIATED WITH THE "CONVENTIONAL" ADIABATIC CONCEPT OF USING THE EXOTIC CERAMIC MATERIALS, VERY HIGH INTERNAL TEMPERATURES, SPECIAL OILS AND THE INFINITE DIFICULTY OF THE ASSOCIATION OF THE CERAMIC THERMAL BARIERS ON METALIC COMPONENTS.**

THE COOLING ENERGY IS "SELF RECOVERED" IN A PROCESS OF REGENERATION AND COGENERATION.

THE CONCEPT IS BASED ON A CONCENTRIC HEAT EXCHANGING CYLINDER LINER, IN PERMANENT CONTACT WITH THE WORKING CYLINDER AND THE ENGINE CYCLE.

IN THE COMPRESSION STROKE A SMALL PORTION OF THE COMPRESSED AIR IS TRANSFERRED IN A CONCENTRIC JACKET, IN WHICH THE COMPRESSED AIR IS ABSORBING THE HEAT TRANSFERRED FROM THE WORKING CYLINDER SPACE.

IN THE EXPANSION STROKE THE HEATED COMPRESSED AIR IS RETURNING IN THE WORKING CYLINDER , PRODUCING THE USEFUL WORK EQUIVALENT WITH THE RECOVERED COOLING ENERGY.

CONTEMPORARY WITH THE FUEL INJECTION AND THE COMBUSTION IN THE WORKING CYLINDER, AT THE BOTTOM OF THE CONCENTRIC JACKET IS INJECTED TANGENTIALLY A QUANTITY OF HIGH PRESSURE PURE WATER .

THIS INJECTED WATER , BY RAPID PROGRESSING ,IS ABSORBING THE REST OF THE COOLING ENERGY, AN BY TRANSFORMATION IN A HIGH PRESSURE STEAM IS PUSHING ALL THE COMPRESSED AIR BACK IN THE WORKING CYLINDER.

FINALLY THE HIGH PRESSURE STEAM IS EXPANDED IN THE WORKING CYLINDER IN A TIPICAL RANKINE CYCLE, ASSOCIATED WITH THE INTERNAL COMBUSTION CYCLE , PRODUCING AN INTERNAL COGENERATION TOTAL ENERGY CYCLE.

THE TOTAL THERMAL CYCLE IS THE SYNERGISTIC ASSOCIATION AND TOTAL ENERGY INTEGRATION OF THE HIGHEST PRESSURE THERMAL CYCLE, WITH A WARM AIR REGENERATION CICLE, AND A RANKINE COGENERATION CYCLE , ACHIEVING A COMPLETE ADIABATIC EFFECT OF AVOIDING THE LOST OF THE COOLING ENERGY, AND THE TOTAL ELIMINATION OF THE COOLING SYSTEM.

THE REZULT IS

THE ABSOLUTE MAXIMIZATION OF THE THERMODYNAMIC CYCLE.

ALL THESE FEATURES AND CARACTERISTICS ARE INCORPORATED IN

THE ECA DESIGN.

TASK1.2 ENGINE THERMAL CYCLE ANALYSIS.

THE COMBINED TYPE OF APPLICATIONS AND MISSIONS IN WHICH IS INTERESTED DARO AND DARPA AND THE DETERMINATION OF THE COMMON ENGINE TECHNOLOGY IS IMPOSING A LARGE ANALYSIS TO SATISFY THE LAND AND AIRCRAFT VECHICULAR APPLICATIONS.

UNMANED AERIAL VECHICLE APPLICATION

THE MOST IMPORTANT DIFERENTIATION IS DETERMINATED BY THE VARIATION OF THE AMBIANT CONDITIONS.

FOR LAND APPLICATIONS THE CONDITIONS ARE RELATED TO THE CLIMAT VARIATIONS, WINTER SUMMER, AND SEA AND MOUNTAIN OPERATIONS WITH NOT MORE THAN 8000 FT.

FOR AIRCRAFT ,THE VARIATION OF AMBIANT CONDITIONS ARE MORE IMPORTANT ,IN RELATIONS WITH THE ALTITUDE WHICH IS CHANGING THE AMBIANT PRESSURE AND THE TEMPERATURE ,ON A LARGE SCALE.

TO CONSERV THE PERFORMANCE OF THE UAV VECHICLE,FROM SEA LEVEL TO THE 25,000 FT IS NECESSARY TO HAVE A VARIABLE SUPERCHARGING LEVEL TO MAINTAIN **AN IDEAL CONSTANT PRESSURE** ALLONG ALL THE EVOLUTION OF THE VECHICLE.

FOR MAXIMUM THERMAL EFFICIENCY IS OBVIOUS NECESSARY TO USE THE **MAXIMUM COMPRESSION RATIO POSSIBLE**, WITH THE REASON TO HAVE **A CONSTANT COMBUSTION PRESSURE**, WHICH WILL GUARANTY THE BEST **CONSTANT SPECIFIC FUEL CONSUMPTION.** MORE THAN THAT, THE SPECIFIC MISSION OF THE UAV OPERATION ,WHICH IMPLY TO HAVE A GOOD EFFICIENCY AT MAXIMUM CRUISE OPERATION, BUT MUCH BETTER FUEL CONSUMPTION AT PART LOADS OF 25-30 % WHEN IS LOITERING OVER THE TARGET THE LONGEST TIME OF THE MISSION, IS IN TOTAL

CONTRADICTION WITH THE CONVENTIONAL ENGINE "HOOK CURVE " OF THE SPECIFIC FUEL CONSUMPTION IN RELATION WITH THE POWER VARIATIONS FROM FULL TO PART LOAD.

OUR THERMO ELECTRIC TURBOCOMPOUND ENGINE IS IDEALLY CONCEIVED AND STRUCTURED FOR A FLEXIBLE AND AUTOMATIC ADAPTATION TO THE POWER, SPEED, ALTITUDE, AMBIANT PRESSURE AND TEMPERATURE AND MISSION CARACTERISTICS, BY AN EXTENDED CONSERVATION OF ALL THE BEST CARACTERISTICS AND PERFORMANCES OF THE ENGINE AND THE UAV.

THE CHART 1. IS INDICATING THE EXTENTION OF THE THERMODYNAMIC CYCLE ANALYSIS, AND THE MATRIX OF THE PARAMERIC VARIATION FOR THE DETERMINATION OF ALL THE POTENTIAL BEST REGIMES.

FROM OUR ANALYSIS REZUTED:

1. TO CONSERV THE MAXIMUM COMBUSTION PRESSURE AT THE LEVEL OF 300 BAR, AT ALL THE LOADS ,POWER VARIATION AND ENVIRONEMRNT CONDITIONS.
2. TO CONSERV THE MAXIMUM COMPRESSION PRESSURE EQUAL WITH THE COMBUSTION PRESSURE AT THE LEVEL OF 300 BAR, USING A COMPRESION VOLUMETRIC RATIO OF 30.5/1
3. TO CONSERV THE INTAKE PRESSURE IN THE ENGINE AT 3 BAR
4. TO CONTROL THE INTAKE TEMPERATURE , AND TO EXPLOIT THE LOWER AMBIANT TEMPERATURE FOR THE BEST PERFORMANCES OF THE ENGINE.
5. TO ADJUST THE SUPERCHARGING LEVEL CONTINUOUS IN RELATION WITH THE ALTITUDE ,FOR CONSERVATION OF THE INTAKE PRESSURE.

SOLUTION ; TURBO ELECTRIC SELF ADJUSTED VARIABLE SUPERCHARGING ONE/ TWO STAGES SECVENTIAL OPERATED COMPRESSORS.

STARTING AT SEA LEVEL WITH ONE STAGE 3/1 SUPERCHARGING AND INTERCOOLING. THE FIRST STAGE TURBO ELECTRIC SUPERCHARGER IS IDLING AND BYPASSED.

CLIMBING TO 25,000FT , GRADUALLY THE FIRST STAGE ELECTRIC TURBO SUPERCHARGER IS COMPENSATING CONTINUOUSE , AND CORRECTING THE AMBIANT DROPING PRESSURE, BY A VARIARIABLE RAISING PRESSURE RATIOS , TO MAINTAIN IN THE SECOND STAGE A CONSTANT INTAKE PRESSUR E , AND CONSECVENTLLY A CONSTANT INTAKE 3/1 PRESSURE IN THE ENGINE.

THIS SOLUTION IS POSSIBLE TO BE REALIZED ONLY BY THE ECA ELECTRIC DRIVEN TURBO COMPRESSORS , ASSOCIATED IN A PERMANENT COMPENSATORY MODE FOR CONSERVATION OF THE ENGINE INTAKE PRESSURE AND BY DEFINITION THE COMPRESSION AND COMBUSTION PRESSURE.

CRIUSE MODE, THE ENGINE IS CONSERVING THE POWER AND THE SPECIFIC FUEL CONSUMPTION , BASED ON THE SAME CONSTANT INTAKE PRESSURE , CONSTANT COMPRESION AND COMBUSTION PRESSURE, HAVING AVAILABLE 260 HP AT THE REGIME OF MAXIMUM AIR FUEL RATIO AT 1.95, AND 4500 RPM , FOR MAXIMUM POWER, WITH A CONSTANT THERMAL EFFICIENCY OVER 65% AND A SPECIFIC FUEL CONSUMPTION OF 95 GR/HP AND HOUR= 0.21 LB/HP.HOUR . THE INDICATED MISSION IS USING ONLLY 125 HP AT 4.5 AIR FUEL RATIO, WITH A THERMAL EFFICIENCY OF 78-80 % AND A SPECIFIC FUEL CONSUMPTION REDUCED AT APROX 80 GR/HP AND HOUR= O.176 LB /HP.HOUR.

TARGET LOITERING , WITH 25% POWER , HAVING AVAILABLE 105 HP , BUT USING ONLY 30 HP , THE AIR FUEL RATIO IS ADJUSTED TO 5.5-6.5 , ACHIEVING A THERMAL EFFICIENCY OF 83- 87% AND A SPECIFIC FUEL CONSUMPTION OF 75 GR/HP.HOUR= 0.165 LB/HP.HOUR.

ALL THESE DATA ARE CALCULATED WITH A POTENTIAL VARIATIONS OF 5%, AND SUBJECT TO CONFIRMATION BASED ON A SPECIAL OPTIMIZATION RESEARCH PROGRAM

HIBRID ELECRTRIC VECHICLES APPLICATIONS

THE LAND VECHICLE APPLICATIONS CAN BE SATISFIED WITH A LARGE FAMILY OF ALTERNATIVES , HAVING A COMMON PHISICAL STRUCTURE DIFERENTIATED ON PARTICULAR APPLICATIONS , POWER DENSITY , ROTATION LEVEL AND PARAMETRIC CARACTERISTICS.

THE BASIC ENGINE WILL BE STRUCTURED TO BE ABLE TO WORK AT 300 – 350 BAR PEACK COMBUSTION PRESSURE. THIS PRESSURE WILL BE THE REZULT OF THE MULTIPLE COMBINATIONS OF COMPRESSION RATIO AND SUPERCHARGING LEVEL,AND AIR /FUEL RATIOS CONTAINED IN THE CHARTS 1-----8.

FOR EACH COMPRESSION RATIO WILL CORRESPOND A PARTICULAR SUPERCHARGING LEVEL, REZULTING THE SAME MAXIM PEACK COMBUSTION PRESSURE OF 300 – 350 BARR NOMINAL FIELD OF COMBUSTION VARIATIONS.

THE BASIC CONCEPT OF LOAD VARIATIONS FROM FULL LOAD TO PART LOADS IS ACCOMPLISHED BY DIFFERENT AIR/FUEL RATIOS, AND CONSTANT SUPERCHARGING ,CONSTANT COMPRESSION PRESSURE AND CONSTANT COMBUSTION PRESSURE. ALL OF THESE WILL GUARANTEE THE BEST THERMAL EFFICIENCY, EVEN BETTER THAN AT FULL LOAD AND THE BEST LOWEST SPECIFIC FUEL CONSUMPTION AT ALL LOADS .

THE TURBO ELECTRIC SUPERCHARGING HAVING 3/1 PRESSURE RATIO IN FIRST STAGE CORRESPONDING TO A COMPRESSION RATIO OF 30.5/1 CAN BE PRPORTIONALLY ADJUSTED AT 13.5 /1 AT THE SUPERCHARGING LEVEL OF 9/1 PRESSURE RATIO, IN TWO STAGES.

WITH THIS WIDE FIELD OF PARAMETRIC VARIATIONS A

UNIC FAMILY OF ENGINES WILL COVER :

BMEP = 10—26---50 KG/CM2

LITRIC POWER HP/L = 100—260—500 HP/L AT 4500---5500 RPM

THERMAL EFFICIENCY NE = 60-------80 %

THIS MODULIZED FAMILY OF ENGINES CAN COVER WITH ONE SET OF COMMON PARTS A FIELD OF POWER

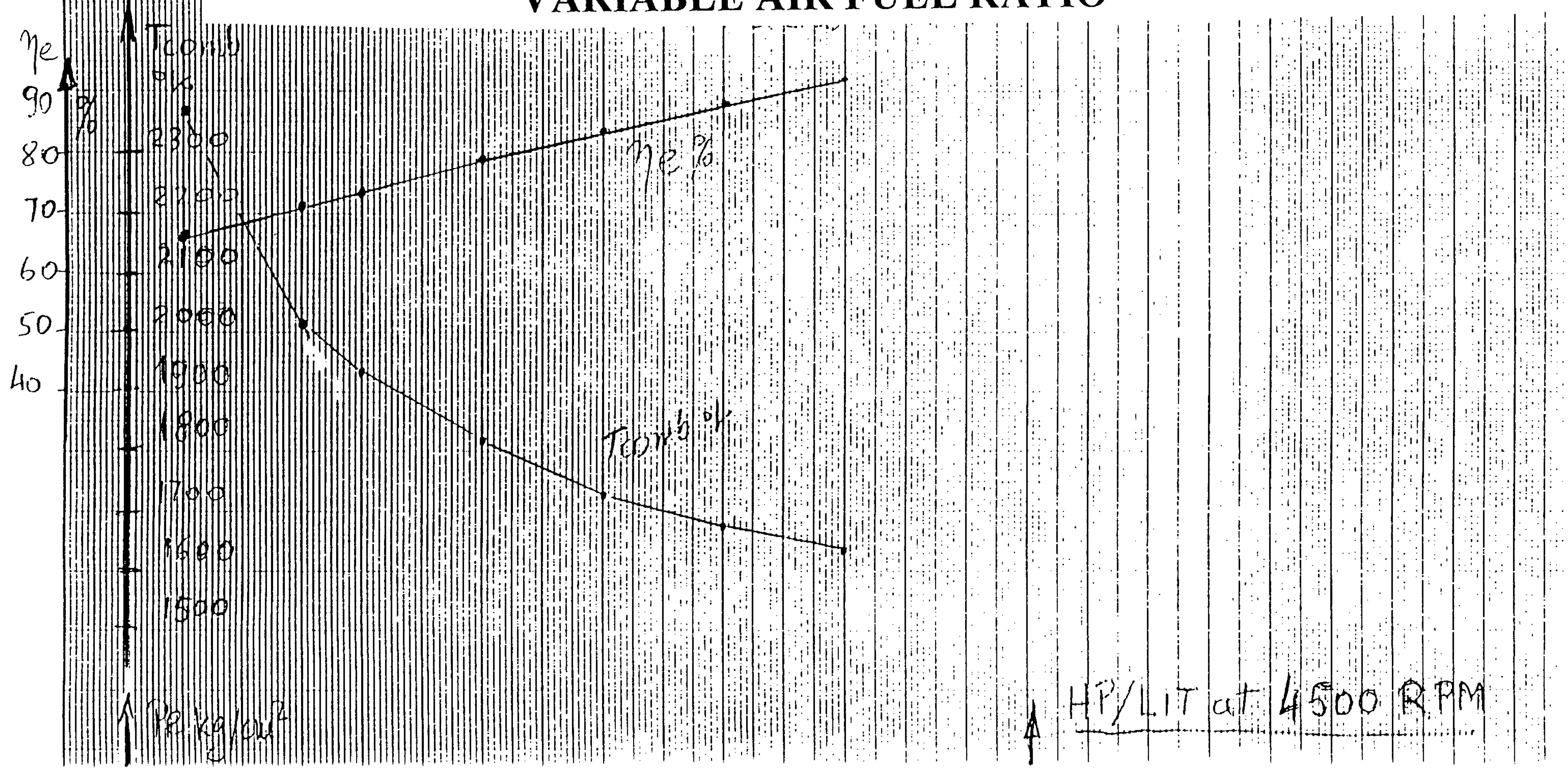
100------------------1500 ---------------------3000 HP

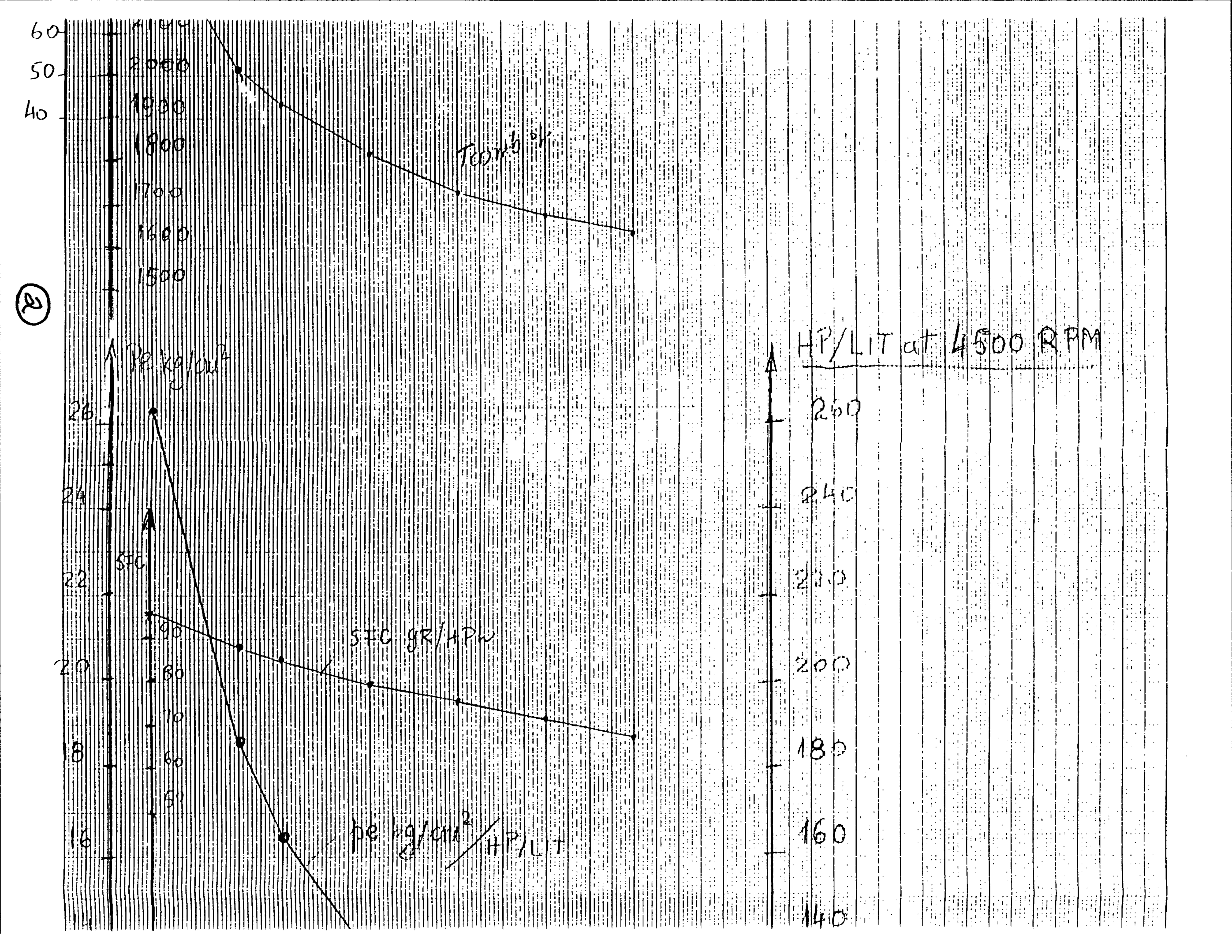
WITH MODULES OF 1--------2-------------3 ----------------------------6 CYLINDERS

SATISFYING ALL THE MILITARY AND COMMERCIAL APPLICATIONS

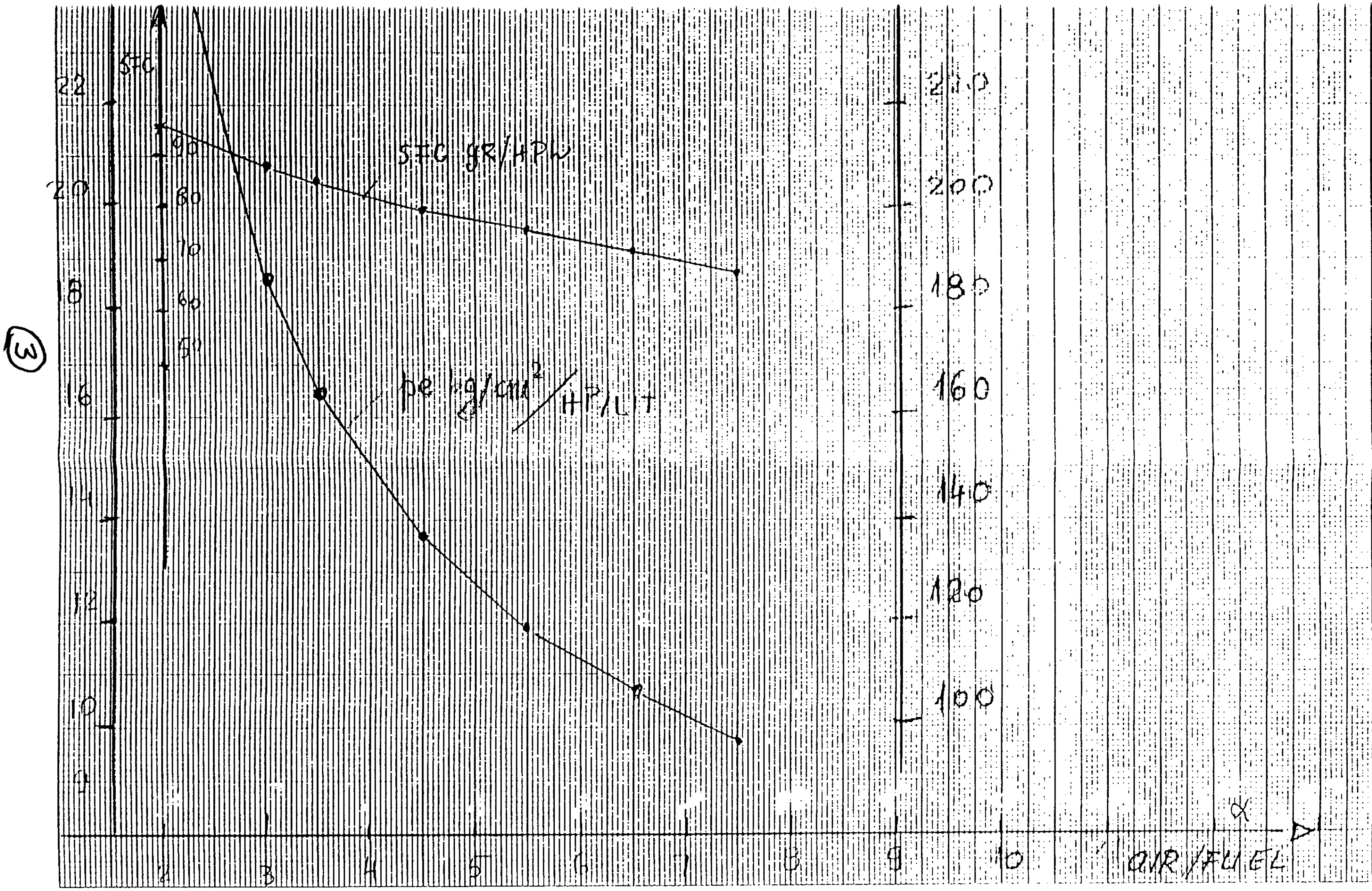
(1)

THEMOELECTRIC COMPOUND ENGINE
COMBUSTION PRESSURE = 300 BAR = 4500 PSI
CONSTANT SUPERCHARGING/TURBOCHARING ps =3
CONSTANT COMPRESSION RATIO Σ = 30.5
VARIABLE AIR FUEL RATIO





②
60
50
40
2000
1900
1800
1700
1600
1500
Tcomb °K
pe kg/cm²
26
24
22
20
18
16
SFC
90
80
70
60
50
SFC gR/HPh
pe kg/cm²
HP/LIT
HP/LIT at 4500 RPM
260
240
220
200
180
160
140


SFC gR/HPW
pe kg/cm²/HP/LIT
AIR/FUEL
α
SFC
22
20
18
16
14
12
10
90
80
70
60
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210
200
180
160
140
120
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DIAGRAM 1

THERMODYNAMIC CYCLE ANALYSIS THERMODYNAMIC COMPOUND ENGINE
TWO STROKE, TOTAL INTAKE, TOTAL EXHAUST

SEA LEVEL	To = 290°k; Po =1.0 Bar							VARIABLE COMBUSTION PRESSURE			
Constant Combustion Pressure	300	304	307	310	309		302	152	201	254	310
								VARIABLE COMPRESSION RATIO			
Compression Ratio	30.5	22.5	21	18.5	16.5		13.5	11	.13.5	16	18.5
Supercharging Level	3	4.5	5	6	7	8	9	**CONSTANT SUPERCHARGING 6 BAR**			
Air/Fuel Ratio	1.95	1.95	1.95	1.95	1.95		1.95	**CONSTANT AIR/FUEL RATIO ∝ = 3**			
	3	3	3	3	3		3	**MAXIMUM °k COMBUSTION TEMPERATURE**			
	3.5	3.5	3.5	3.5	3.5		3.5	1804	1900	1987	2066
	----	4.0	----	----	----	----	----	**BMEP kg/cw²**			
	4.5	4.5	4.5	4.5	4.5		4.5	23.56	25.3	26.95	28.43
	5.5	5.5	5.5	5.5	5.5		5.5	**SFC gr/hph**			
	6.5	6.5	6.5	6.5	6.5		6.5	119.7	109.3	101.5	95.4
	7.5	7.5	7.5	7.5	7.5		7.5	**η_e %**			
		8.5	8.5	8.5	8.5		8.5	0.52	0.57	0.616	0.65
		9.5	9.5	9.5	9.5		9.5				
				10.5	10.5		10.5				
				11.5	11.5		11.5				
					12.5		12.5				

CHART 1

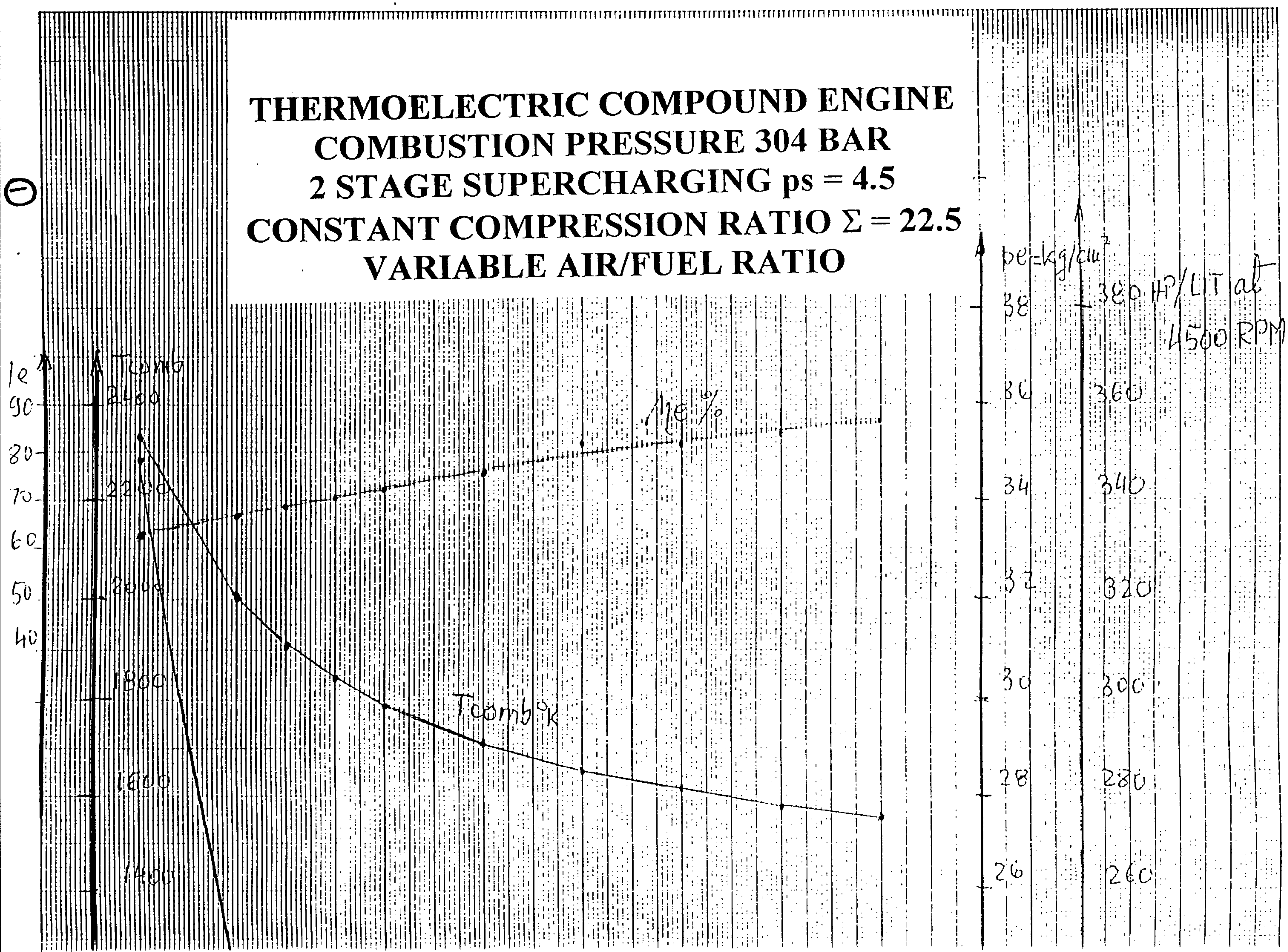
THERMO ELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 300 BARS = 45OO PS
1 CONSTANT PRESSURE SUPERCHARGING/TURBOCHARGING ps = 3
CONSTANT COMPRESSION RATIO $\Sigma = 30$
VARIABLE AIR/FUEL RATIO $\alpha =$

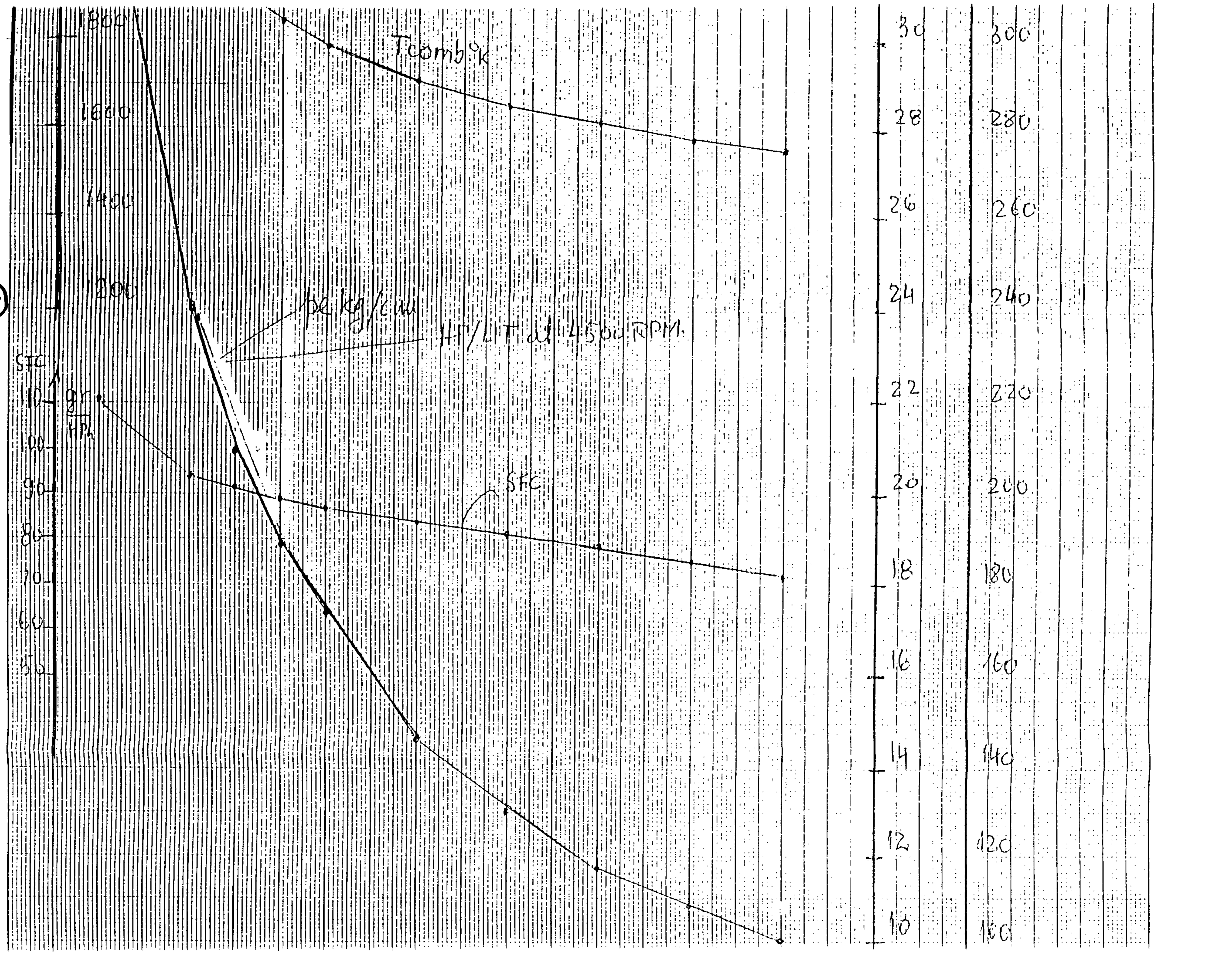
TW0 STROKE
OPPOSED PISTON, TOTAL INTAKE - EXHAUST
SEA LEVEL CONDITIONS

α	1.5	1.95	3	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
T_{comb} °K		2365	2023	1931	1808	1729	1674	1634					
αT		0.2148	0.248	0.2557	0.279	0.301	0.319	0.336					
αc		0.146	0.202	0.225	0.267	0.303	0.334	0.362					
Pe kg/cm^2		26.33	18.55	16.46	13.638	11.82	10.56	9.638					
SFC gr/hph		95.41	88.02	85.068	79.85	75.33	71.35	67.79					
η_e		0.656	0.711	0.736	0.784	0.831	0.877	0.92					

CHART 2

THERMOELECTRIC COMPOUND ENGINE
COMBUSTION PRESSURE 304 BAR
2 STAGE SUPERCHARGING ps = 4.5
CONSTANT COMPRESSION RATIO Σ = 22.5
VARIABLE AIR/FUEL RATIO





Tcomb °K
pe kg/cm
HP/LT at 4500 RPM
SFC
SFC
gr/HPh
1800
1600
1400
1200
110
100
90
80
70
60
50
30
28
26
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260
240
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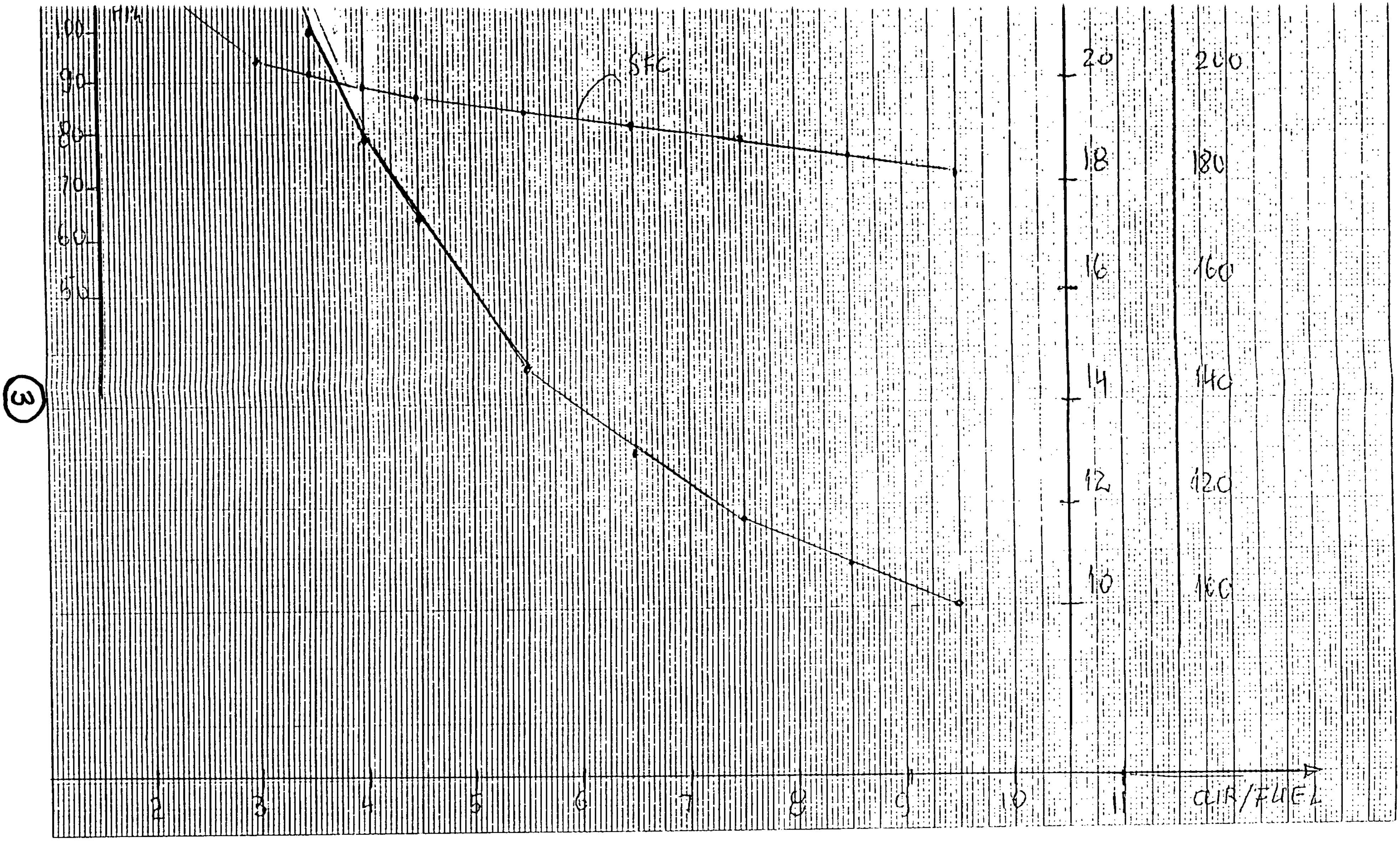
180
160
140
120
100

(2)


HP
100
90
80
70
60
50
SFC
20
18
16
14
12
10
200
180
160
140
120
100
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9
10
11
AIR/FUEL

DIAGRAM 3

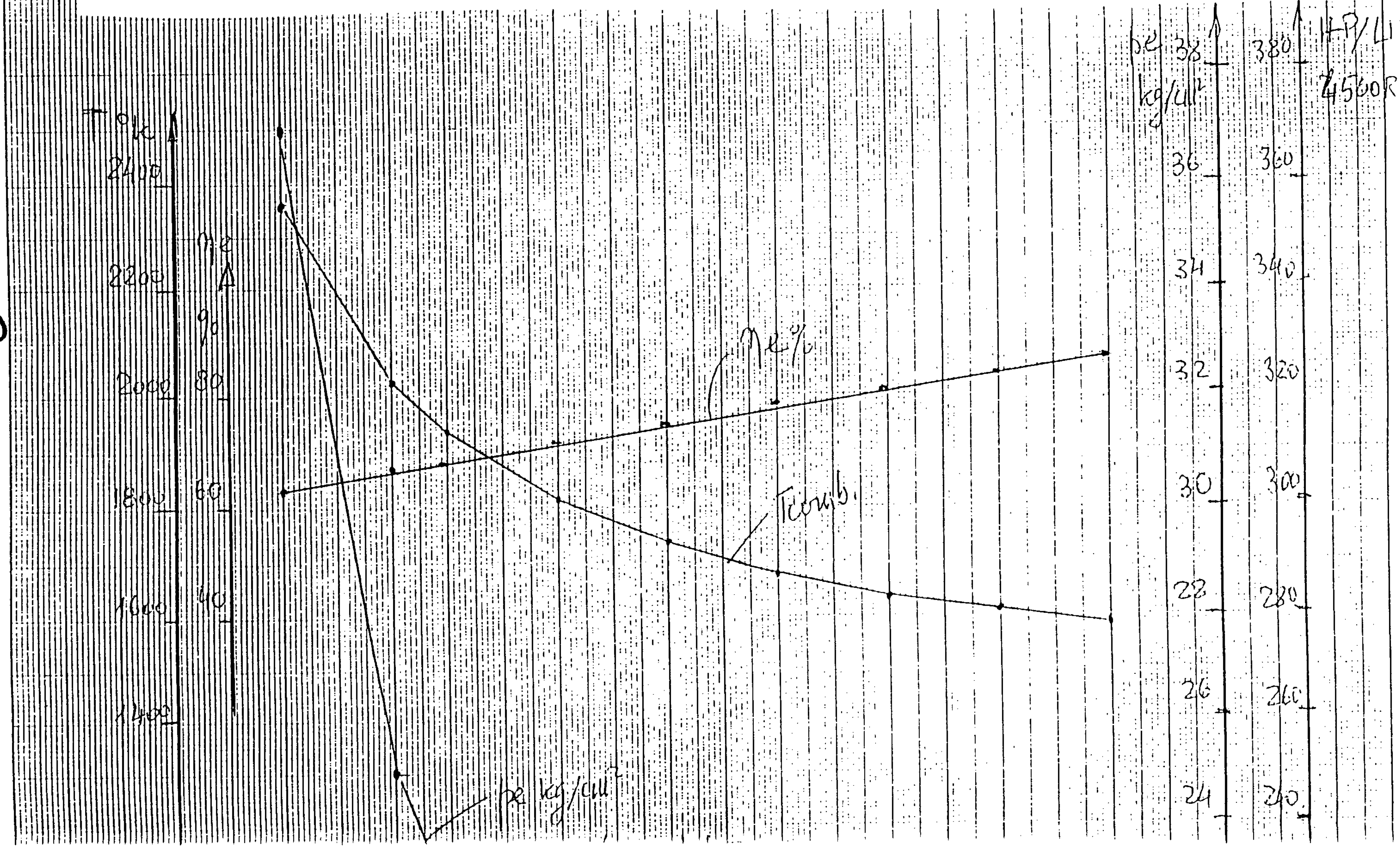
THERMO ELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 304 BARS
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING ps = 4.5 BARS
CONSTANT COMPRESSION RATIO $\Sigma = 22.5$
VARIABLE AIR/FUEL RATIO $\alpha =$

TWO STROKE
OPPOSED PISTON, TOTAL INTAKE - EXHAUST
SEA LEVEL CONDITIONS

α	1.5	1.95	3	3.5	4.0	4.5	5.5	6.5	7.5	8.5	9.5	11.5	12.5
T_{comb} °K		2340	1998	1906	18.37	1783	1704	1649	1609	1578	1554		
αT		0.331	0.374	0.3946	0.413	0.4323	0.466	0.496	0.524	0.548	0.5708		
αc		0.231	0.319	0.357	0.391	0.423	0.482	0.533	0.579	0.62	0.657		
Pe kg/cm^2		34.8	24.06	21.1	18.9	17.27	14.781	13.04	11.76	10.78	10.0		
SFC gr/hph		100.2	94.2	91.78	89.55	87.46	83.64	80.20	77.068	74.19	71.53		
η_e		0.624	0.664	0.682	0.699	0.715	0.748	0.78	0.81	0.843	0.875		

CHART 3

THERMOELECTRIC COMPOUND ENGINE
MAX COMBUSTION PRESSURE = 307 BAR
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING = 5 BAR
CONSTANT COMPRESSION RATIO Σ = 21



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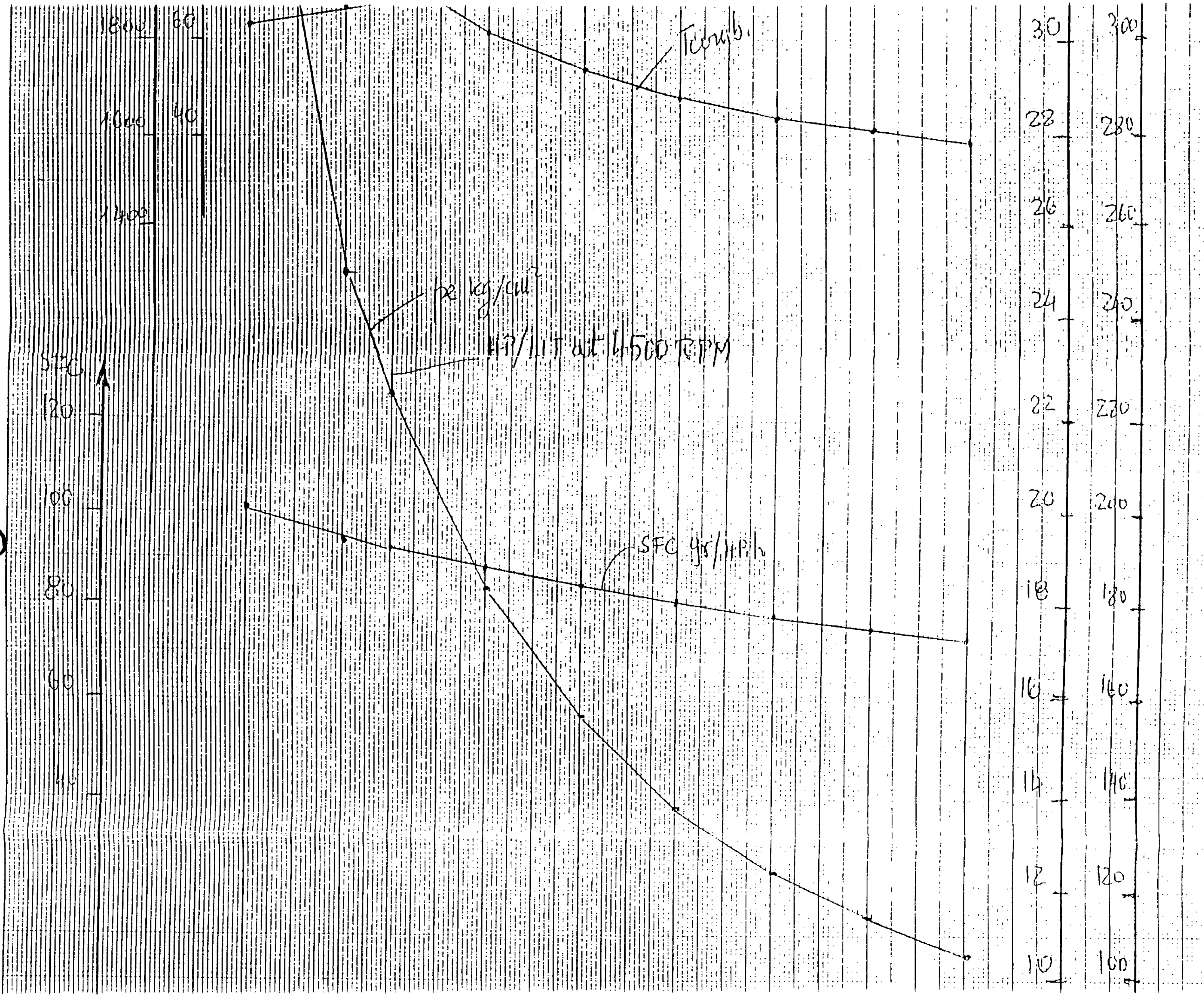
Tcomb.
pe kg/cm²
HP/lit at 4500 RPM
SFC gr/HP.h
SFC
1800
1600
1400
60
40
120
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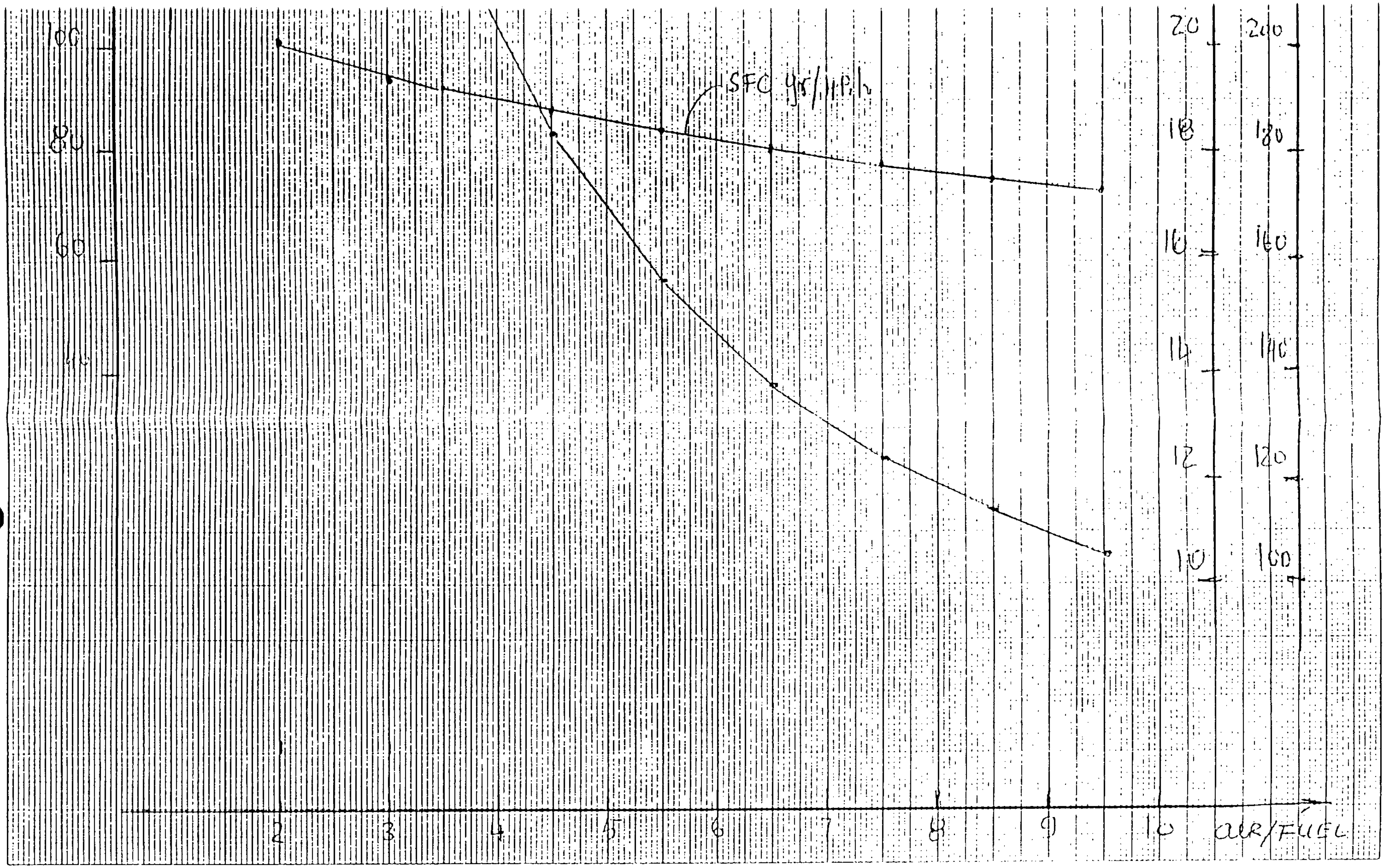
SFC gr/HP.h
100
80
60
20
18
16
14
12
10
200
180
160
140
120
100
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3
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5
6
7
8
9
10
air/FUEL

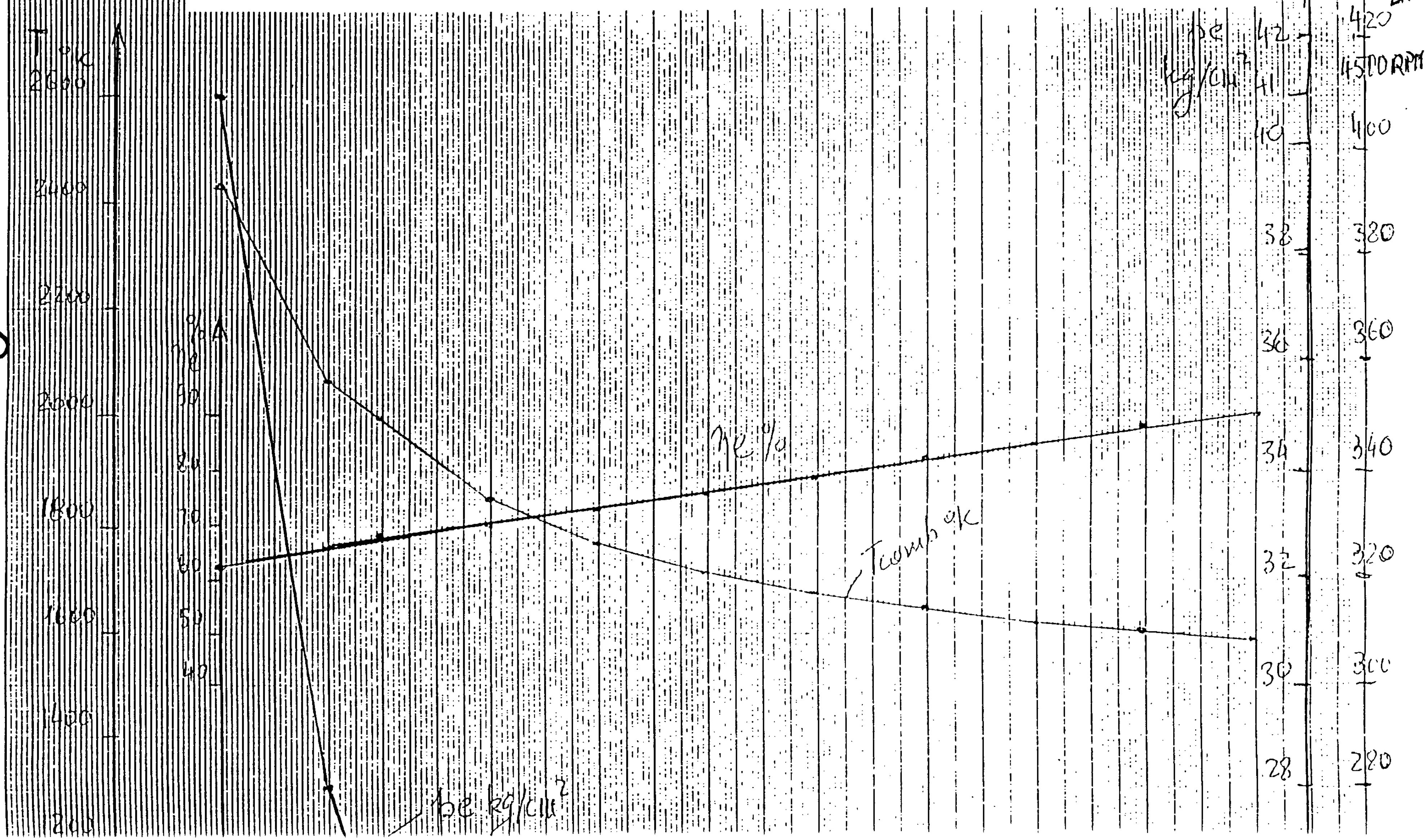
DIAGRAM 4

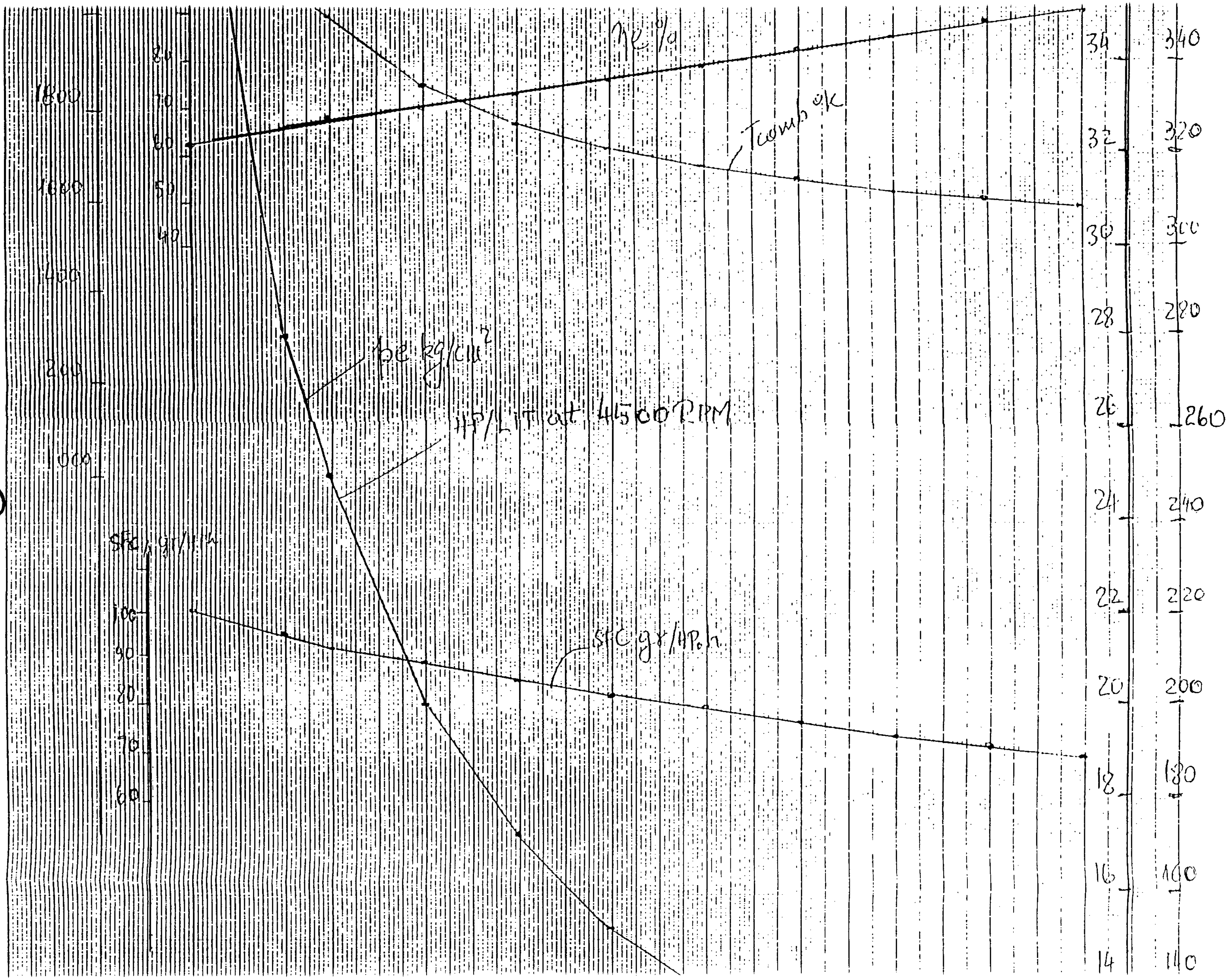
THERMO ELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 307 BARS
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING ps = 5 BARS
CONSTANT COMPRESSION RATIO $\Sigma = 21$
VARIABLE AIR/FUEL RATIO α =

TWO STROKE
OPPOSED PISTON, TOTAL INTAKE - EXHAUST
SEA LEVEL CONDITIONS

α	1.5	1.95	3	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
T_{comb} °K		2366	2024	1933	1809.8	1731	1676	1636	1605	1580			
αT		0.367	0.415	0.4378	0.479	0.5174	0.551	0.581	0.6085	0.633			
αc		0.255	0.352	0.392	0.466	0.529	0.586	0.635	0.68	0.72			
Pe kg/cm^2		37.069	25.58	22.49	18.345	15.68	13.82	12.46	11.41	10.58			
SFC gr/hph		100.4	94.5	92.167	87.916	84.15	80.75	77.6	74.8	72.16			
η_e		0.623	0.662	0.679	0.712	0.744	0.775	0.806	0.837	0.867			

THERMOELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE 310 BAR
2 STAGE SUPERCHARGING/TURBOCHARGING ps = 6BAR




ηe %
Tcomb °K
pe kg/cm²
HP/LIT at 4500 RPM
sfc gr/HP.h
sfc gr/h
1800
1600
1400
1200
1000
80
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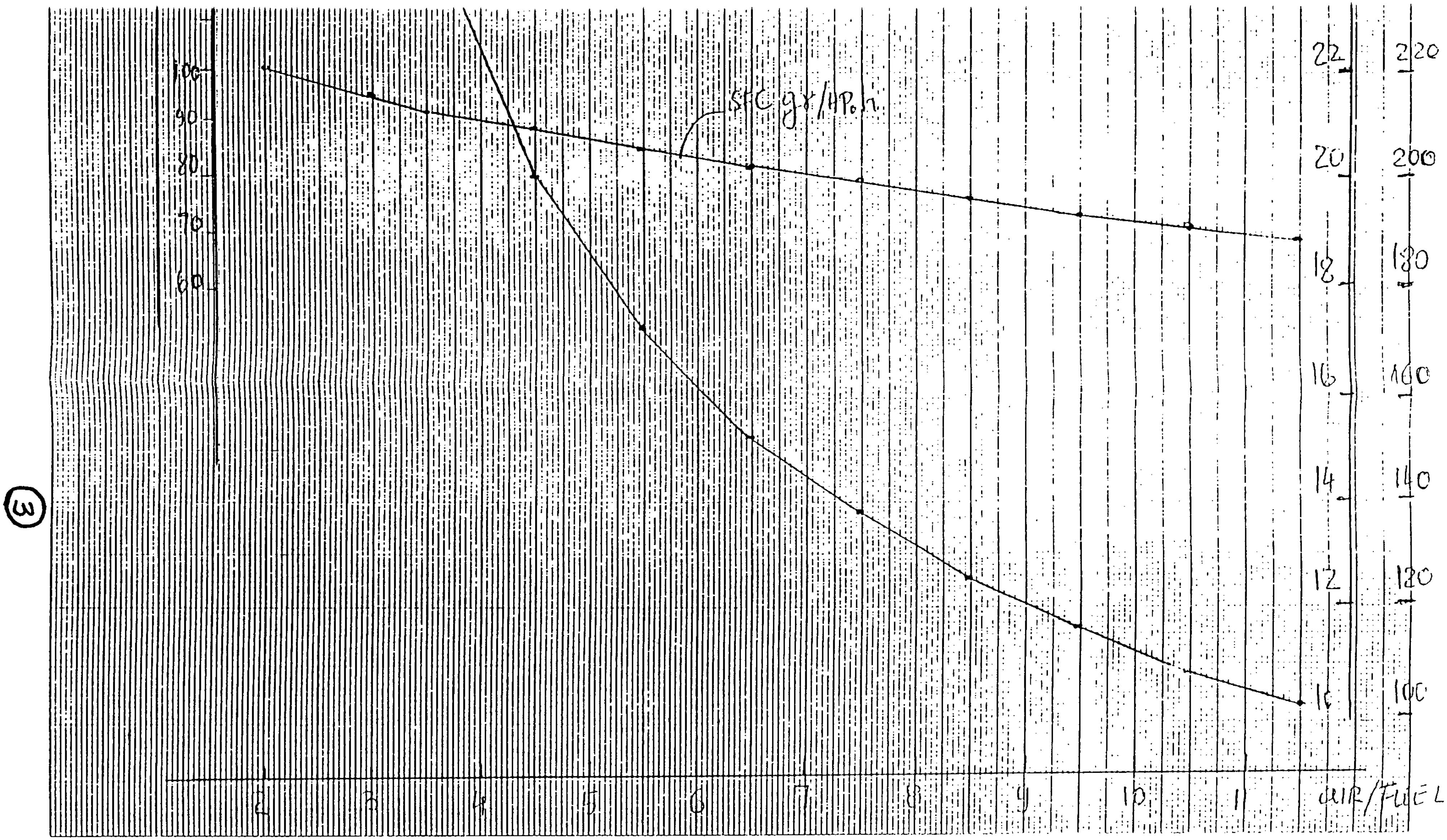
SFC gr/HP.h
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80
70
60
22
20
18
16
14
12
10
220
200
180
160
140
120
100
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8
9
10
11
air/FUEL

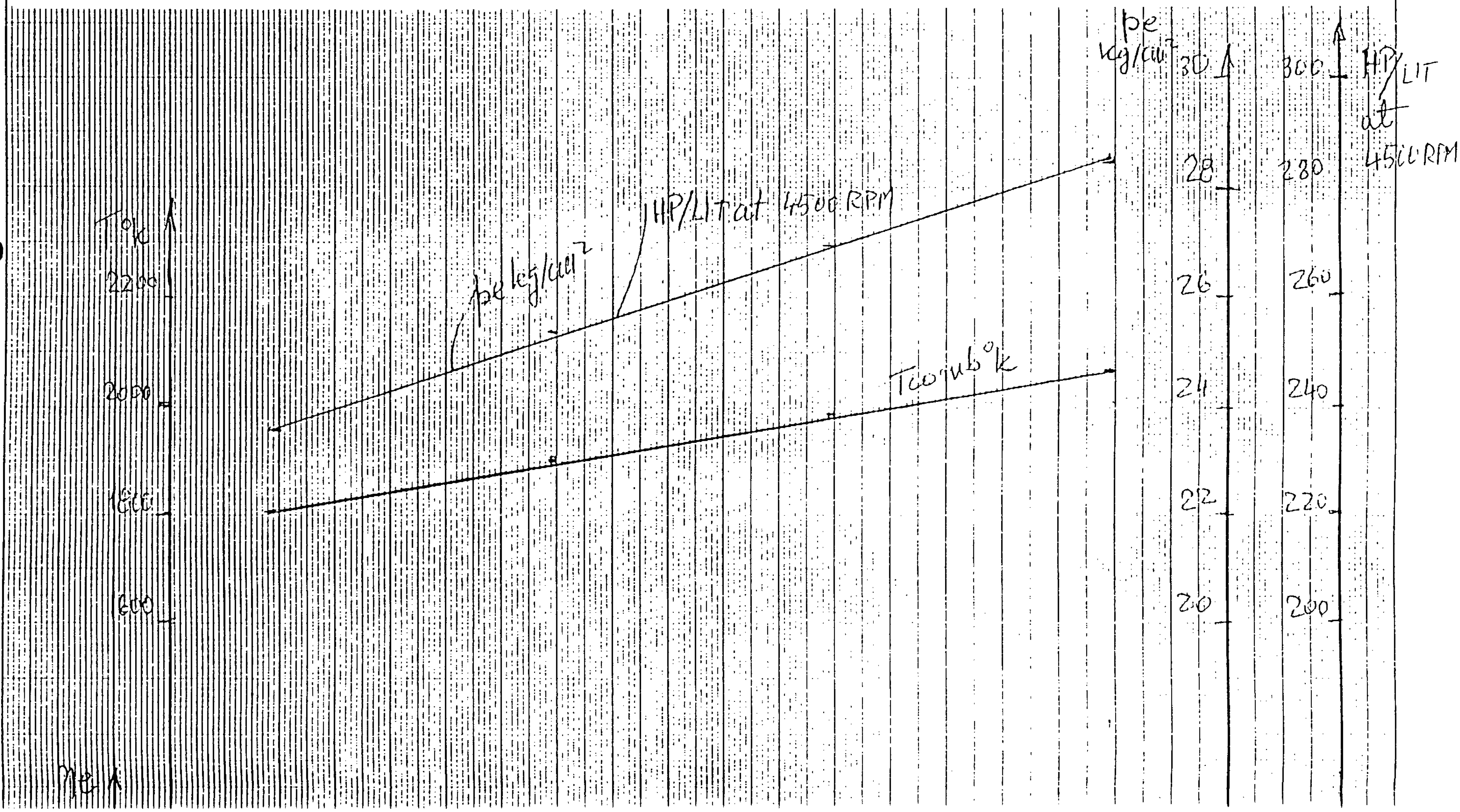
DIAGRAM 5

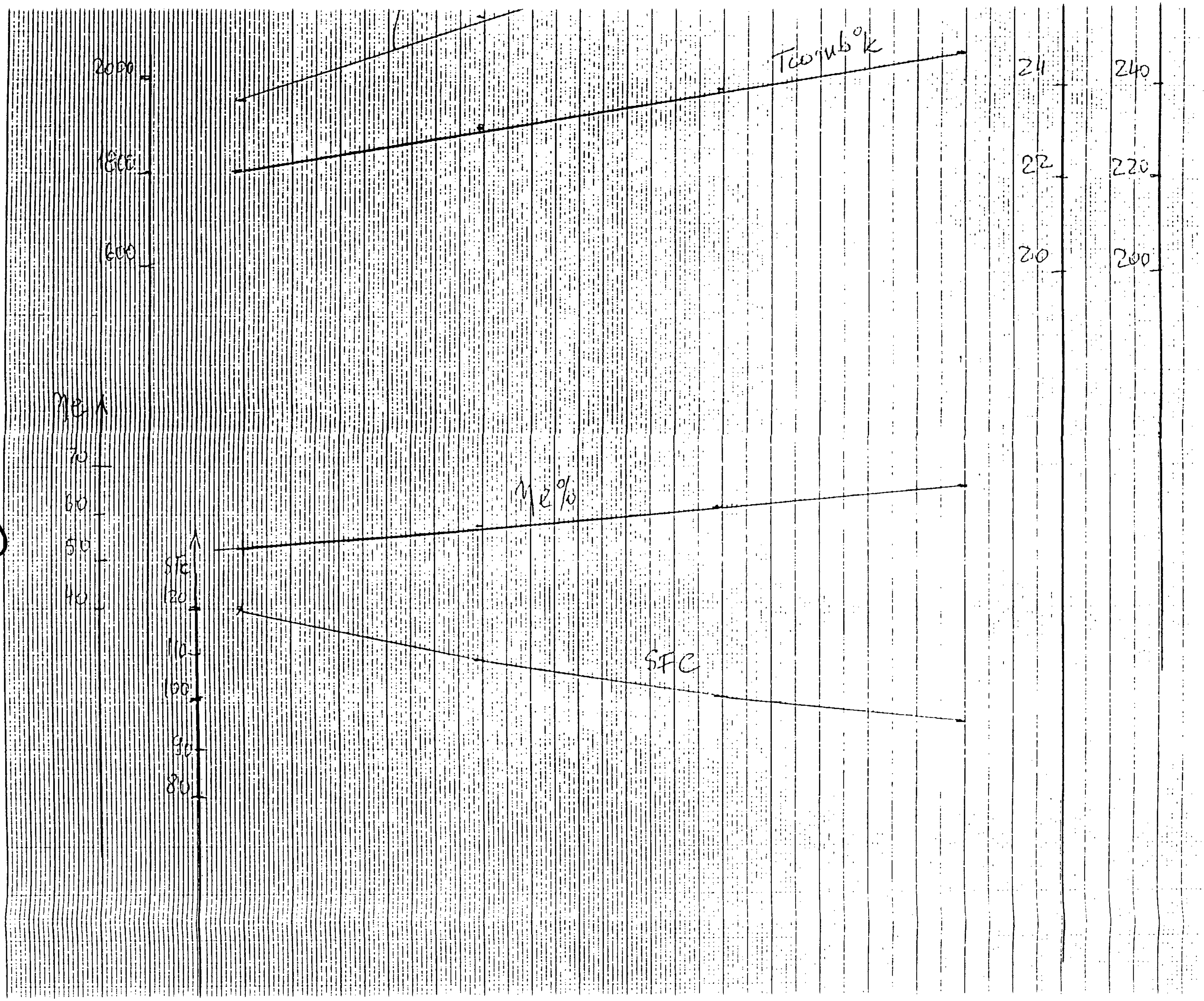
THERMO ELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 310 BARS
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING ps = 6.0 BARS
CONSTANT COMPRESSION RATIO $\Sigma = 18.5$
VARIABLE AIR/FUEL RATIO $\alpha =$

TWO STROKE
OPPOSED PISTON, TOTAL INTAKE - EXHAUST
SEA LEVEL CONDITIONS

α	1.5	1.95	3	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
T_{comb} °K		2426	2066	1993	1851	1772	1718	1678	1647	1622	1603	1586	
α/T		0.4381	0.4941	0.523	0.5711	0.616	0.6561	0.692	0.7242	0.7533	0.779	0.803	
α/c		0.299	0.413	0.458	0.546	0.62	0.685	0.743	0.794	0.841	0.882	0.92	
Pe kg/cm^2		41.09	28.4	24.9	20.3	17.33	15.25	13.76	12.55	11.627	10.875	10.25	
SFC gr/hph		100.29	95.4	92.1	89.02	85.37	82.069	79.044	76.2	73.66	71.259	69.01	
η_e		.624	0.656	.679	0.703	0.733	0.76	0.792	0.821	0.849	0.878	0.907	

THERMOELECTRIC COMPOUND ENGINE
CONSTANT 2 STAGE SUPERCHARGIN/TURBOCHARGING ps = 6 BAR
VARIABLE COMPRESSION RATIO
VARIABLE COMBUSTION PRESSURE




Tcomb°K
ηe%
SFC
2000
1800
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240
220
200
ηe
70
60
50
40
SFC
120
110
100
90
80

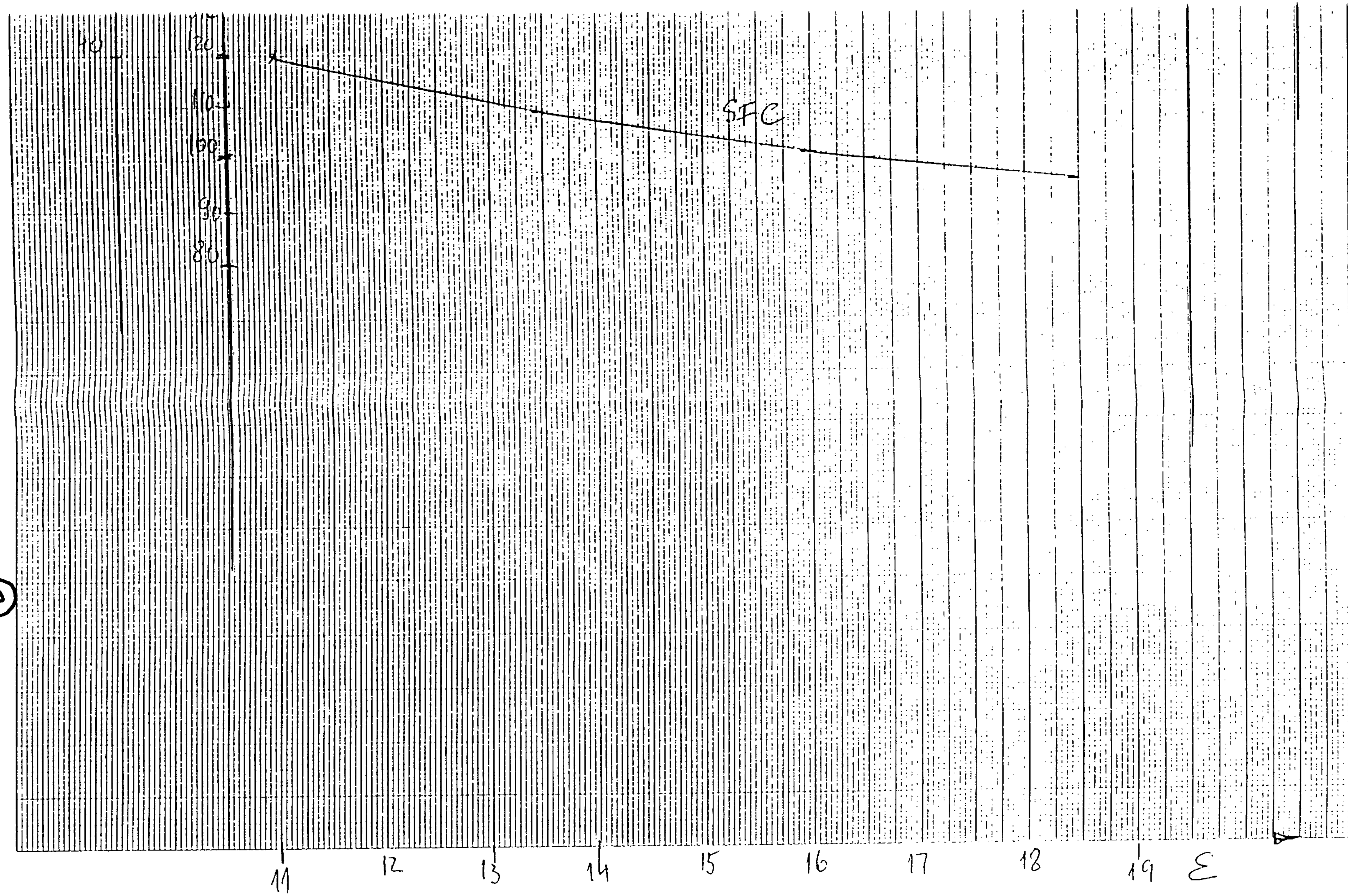
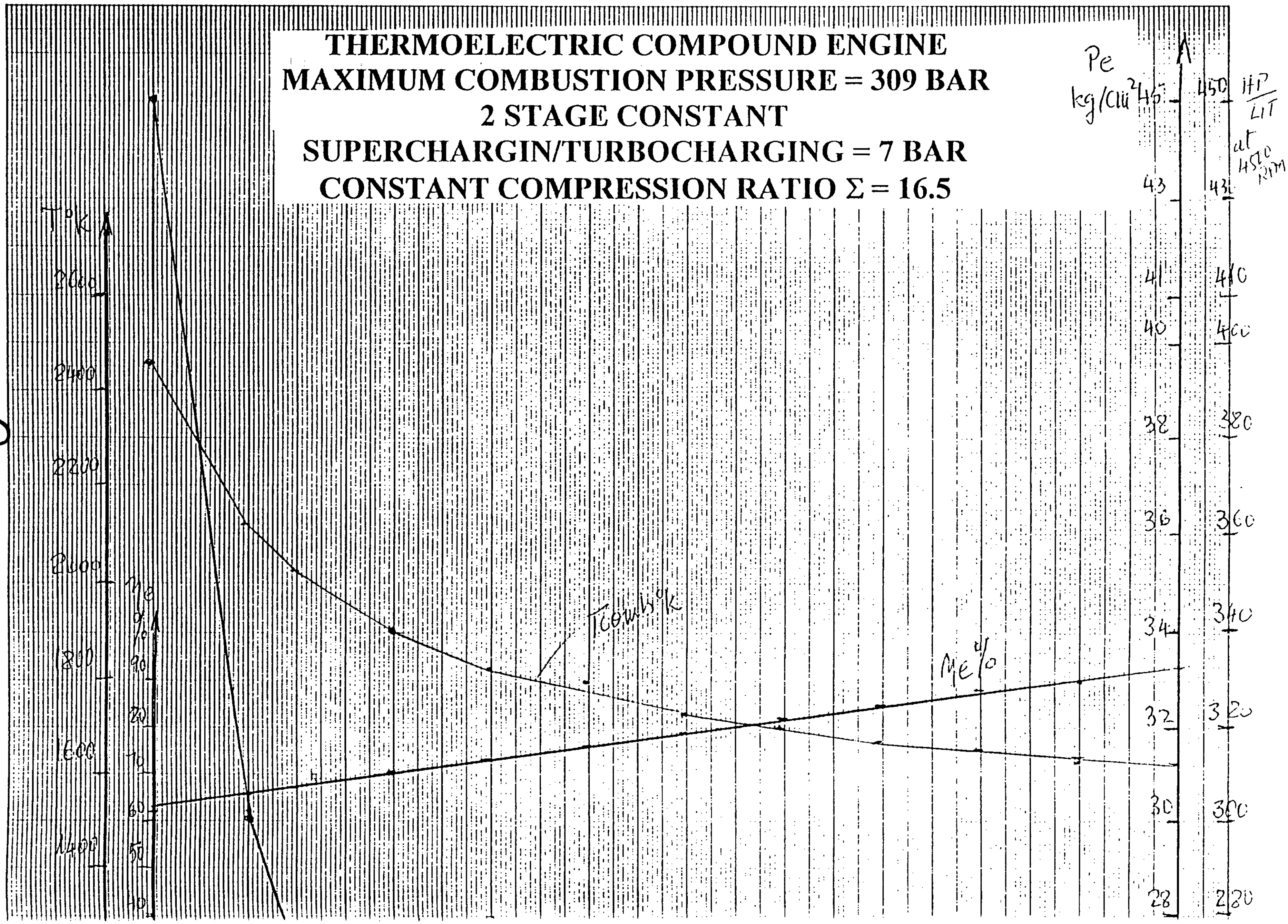


DIAGRAM 6

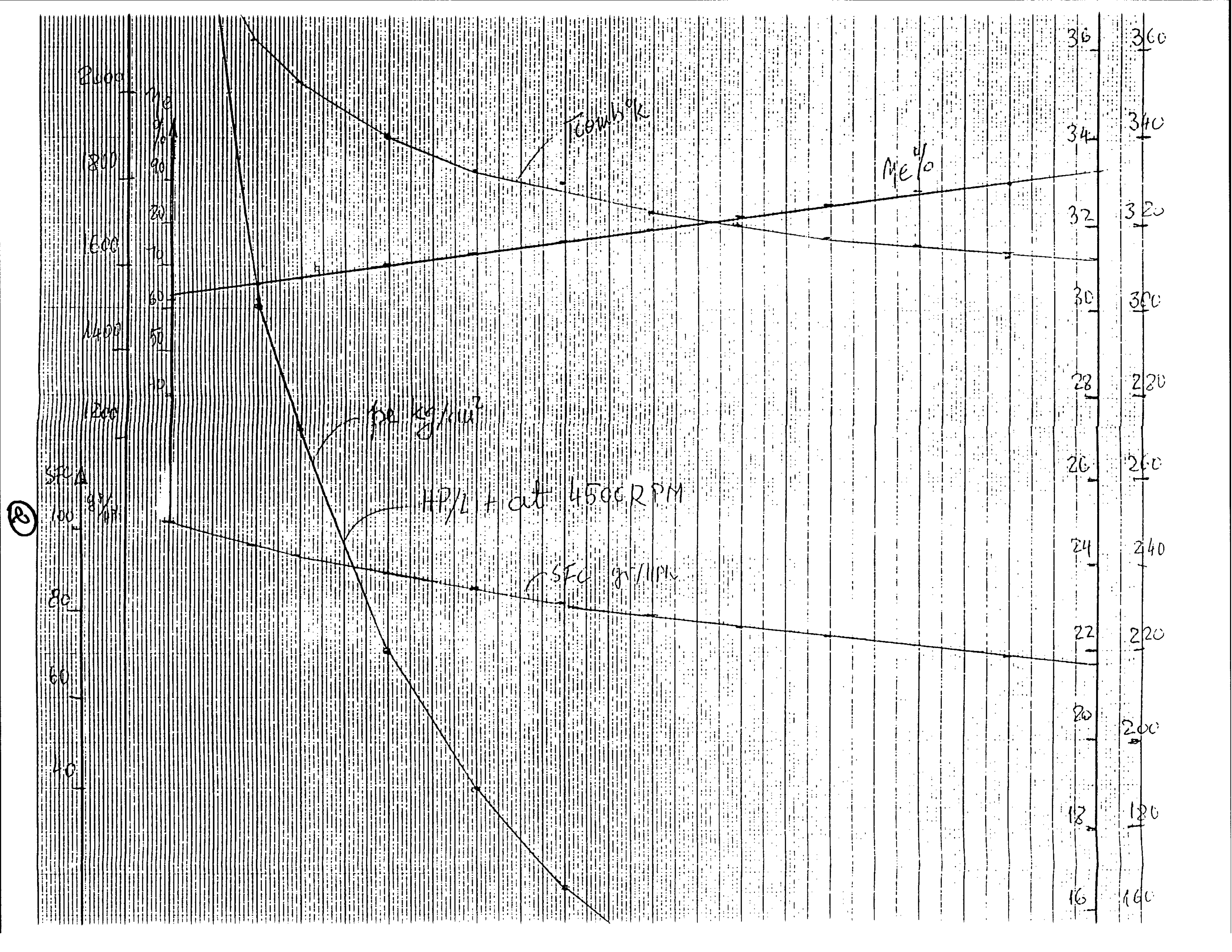
THERMO ELECTRIC COMPOUND ENGINE
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING ps = 6 BARS
CONSTANT AIR/FUEL RATIO $\alpha = 3$

VARIABLE COMPRESSION RATIOS

Σ		11	13.5	16	18.5
Pmax bars		152	201	254	310
T_{comb} °K		1804	1900	1987	2066
αT		0.6407	0.5751	0.5289	0.4941
αc		0.533	0.48	0.442	0.413
Pe kg/cm^2		23.56	25.353	26.95	28.43
SFC gr/hph		119.77	109.299	101.578	95.4
η_e		0.52	0.573	0.616	0.656


THERMOELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 309 BAR
2 STAGE CONSTANT
SUPERCHARGIN/TURBOCHARGING = 7 BAR
CONSTANT COMPRESSION RATIO Σ = 16.5
T°K
2600
2400
2200
2000
1800
1600
1400
ηe %
90
80
70
60
50
40
Tcomb°K
ηe %
Pe kg/cm²
45
43
41
40
38
36
34
32
30
28
HP/LIT at 4500 RPM
450
430
410
400
380
360
340
320
300
280

(1)



Tcowb°K
Me%
pe kg/cm²
HP/L + at 4500 RPM
SFC gr/HPh
SFC gr/HPh
Me %
②

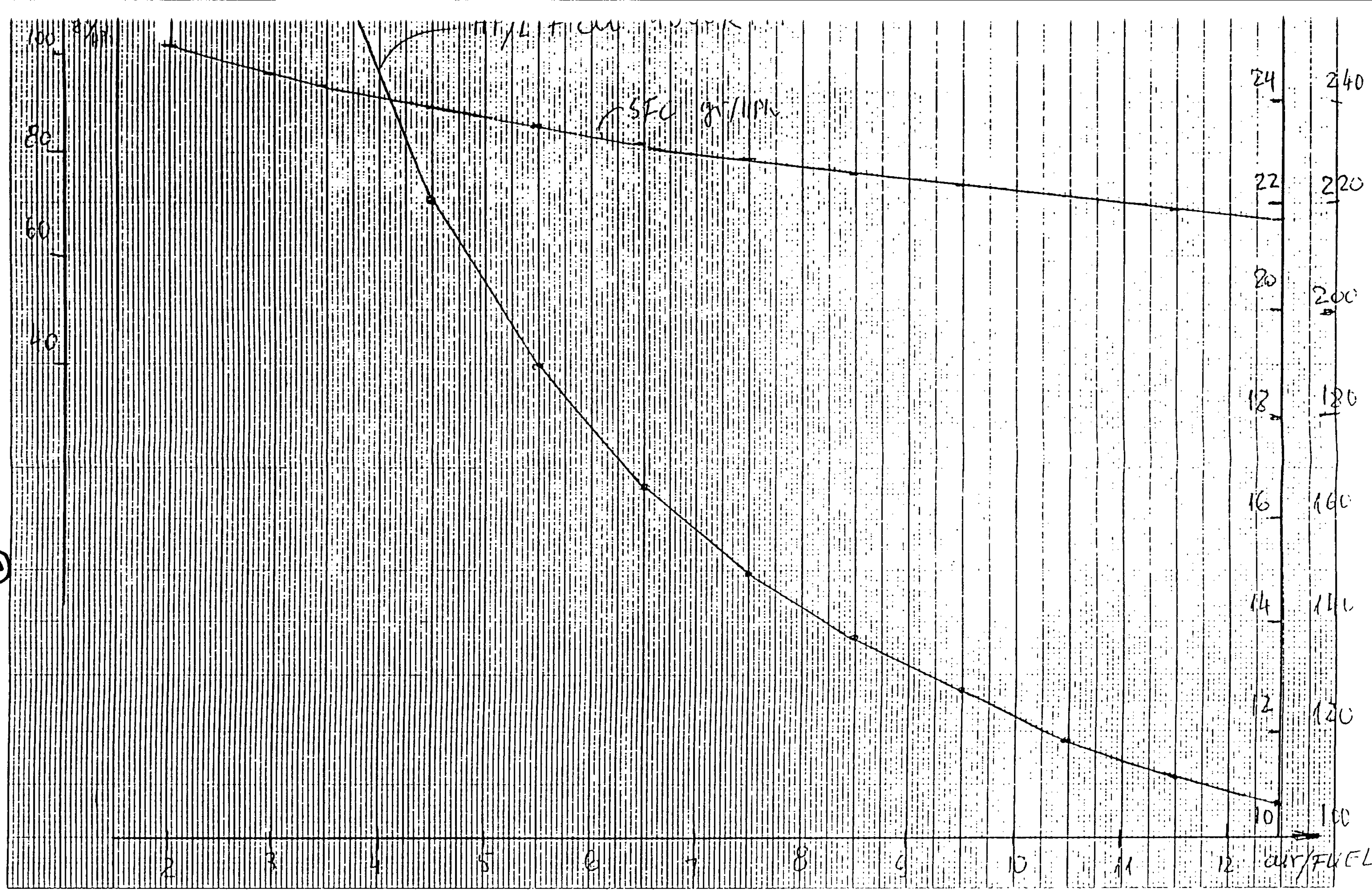

SFC gr/HPh
air/FUEL
2
3
4
5
6
7
8
9
10
11
12
100
80
60
40
24
22
20
18
16
14
12
10
240
220
200
180
160
140
120
100

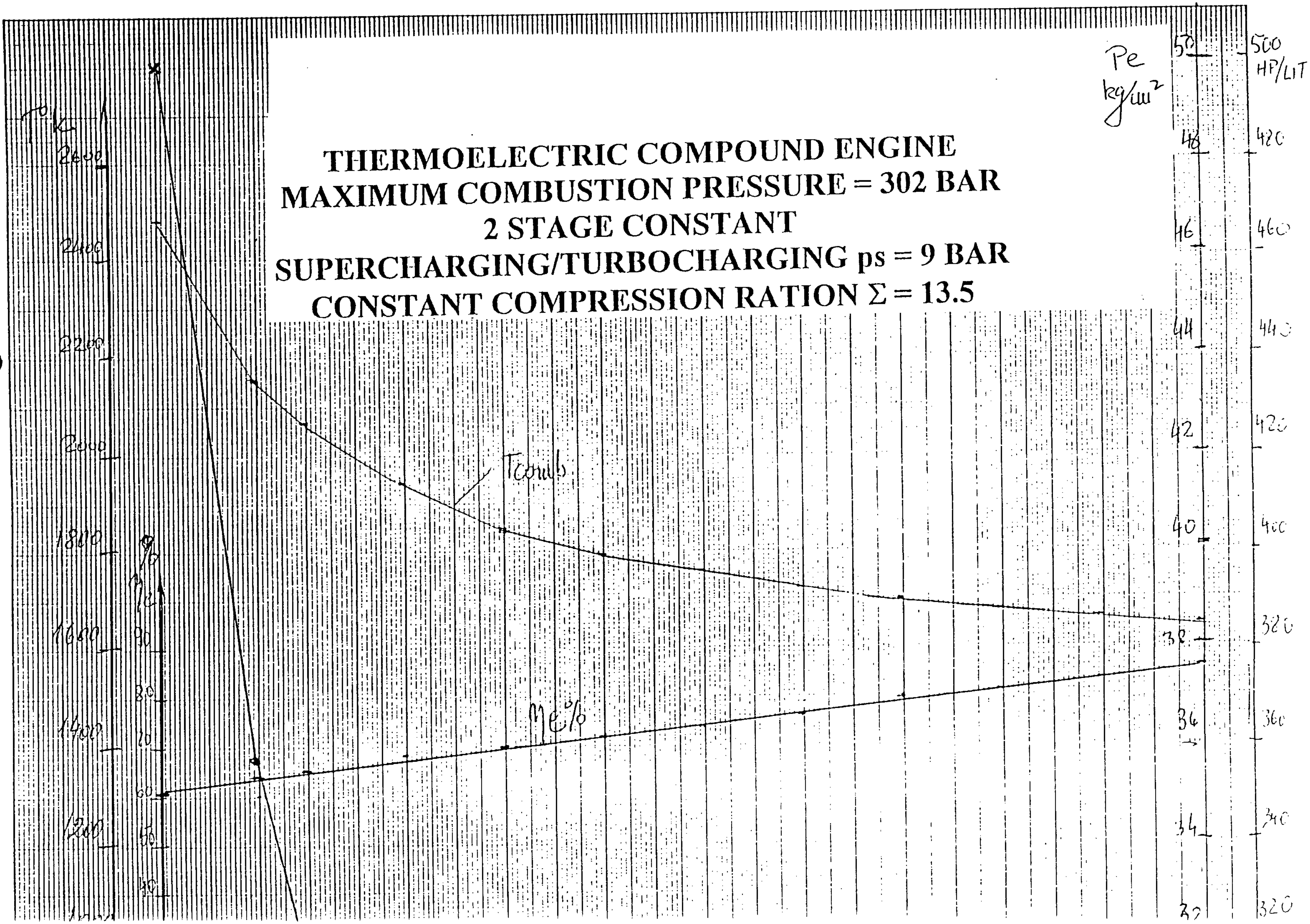
DIAGRAM 7

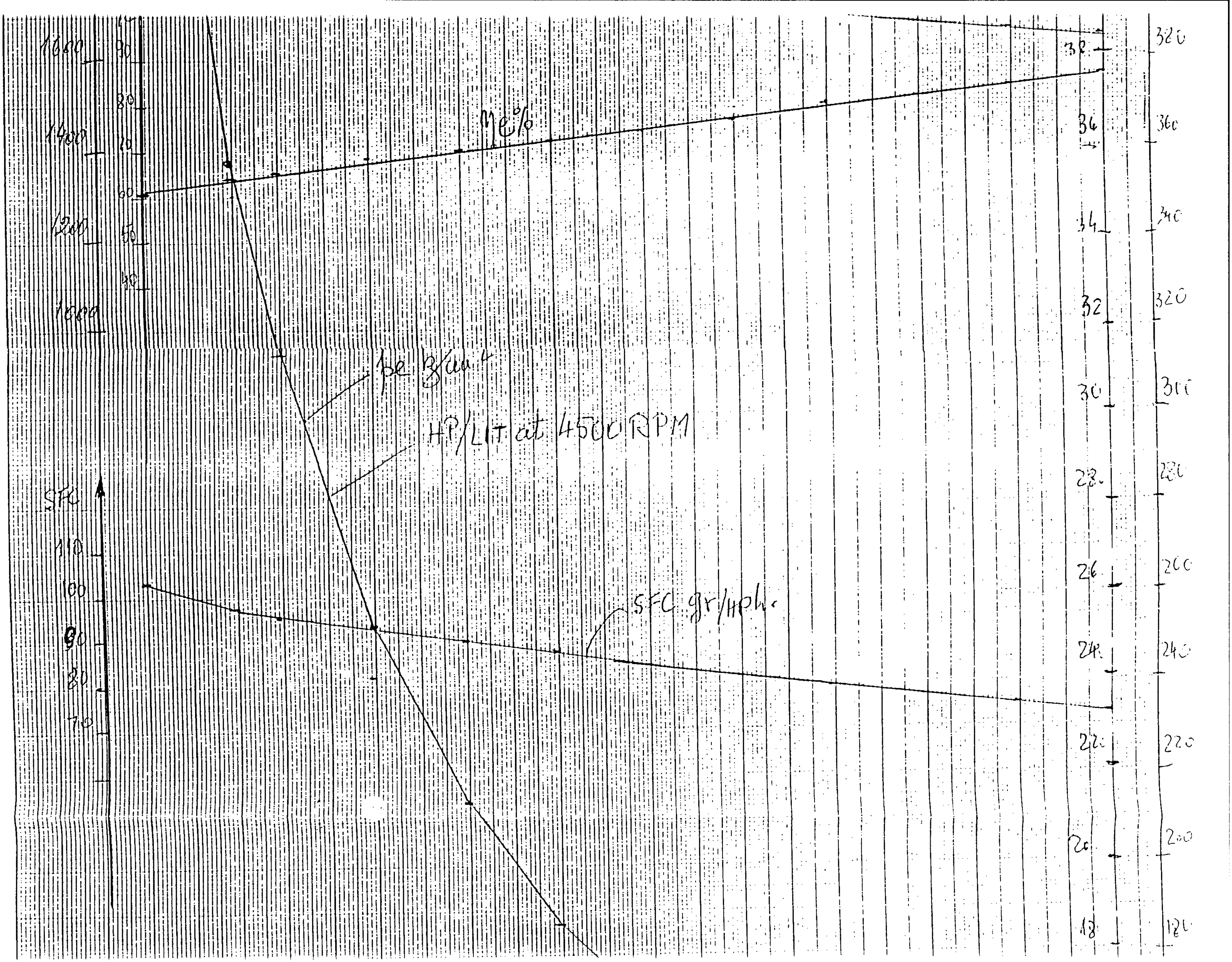
THERMO ELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 309 BARS
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING ps = 7 BARS
CONSTANT COMPRESSION RATIO $\Sigma = 16.5$
VARIABLE AIR/FUEL RATIO $\alpha =$

TWO STROKE
OPPOSED PISTON, TOTAL INTAKE - EXHAUST
SEA LEVEL CONDITIONS

α	1.5	1.95	3	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
T_{comb}°K		2456	2115	2024	1901	1822	1798	1728	1697	1672	1653	1636	1623
αT		0.5051	0.5729	0.604	0.662	0.7143	0.760	0.8019	0.839	0.872	0.902	0.929	0.954
αc		0.342	0.47	0.524	0.619	0.703	0.775	0.84	0.897	0.948	0.994	1.036	1.074
Pe kg/cm^2		45	30.98	27.2	22.135	18.88	16.62	14.9	13.68	12.68	11.863	11.186	10.617
SFC gr/hph		101	95.48	93.2	89.09	85.43	82.11	79.074	76.26	73.66	71.249	68.98	66.87
η_e		0.619	0.655	0.67	0.702	0.73	0.762	0.791	0.82	0.849	0.878	0.907	0.936

1


THERMOELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 302 BAR
2 STAGE CONSTANT
SUPERCHARGING/TURBOCHARGING ps = 9 BAR
CONSTANT COMPRESSION RATION Σ = 13.5
T°K
2600
2400
2200
2000
1800
1600
1400
1200
%
90
80
70
60
50
40
Tcomb
ηe%
Pe
kg/cm²
50
48
46
44
42
40
36
34
500
HP/LIT
480
460
440
420
400
360
340
320


Me%
HP/LIT at 4500 RPM
SFC gr/HPh.
SFC

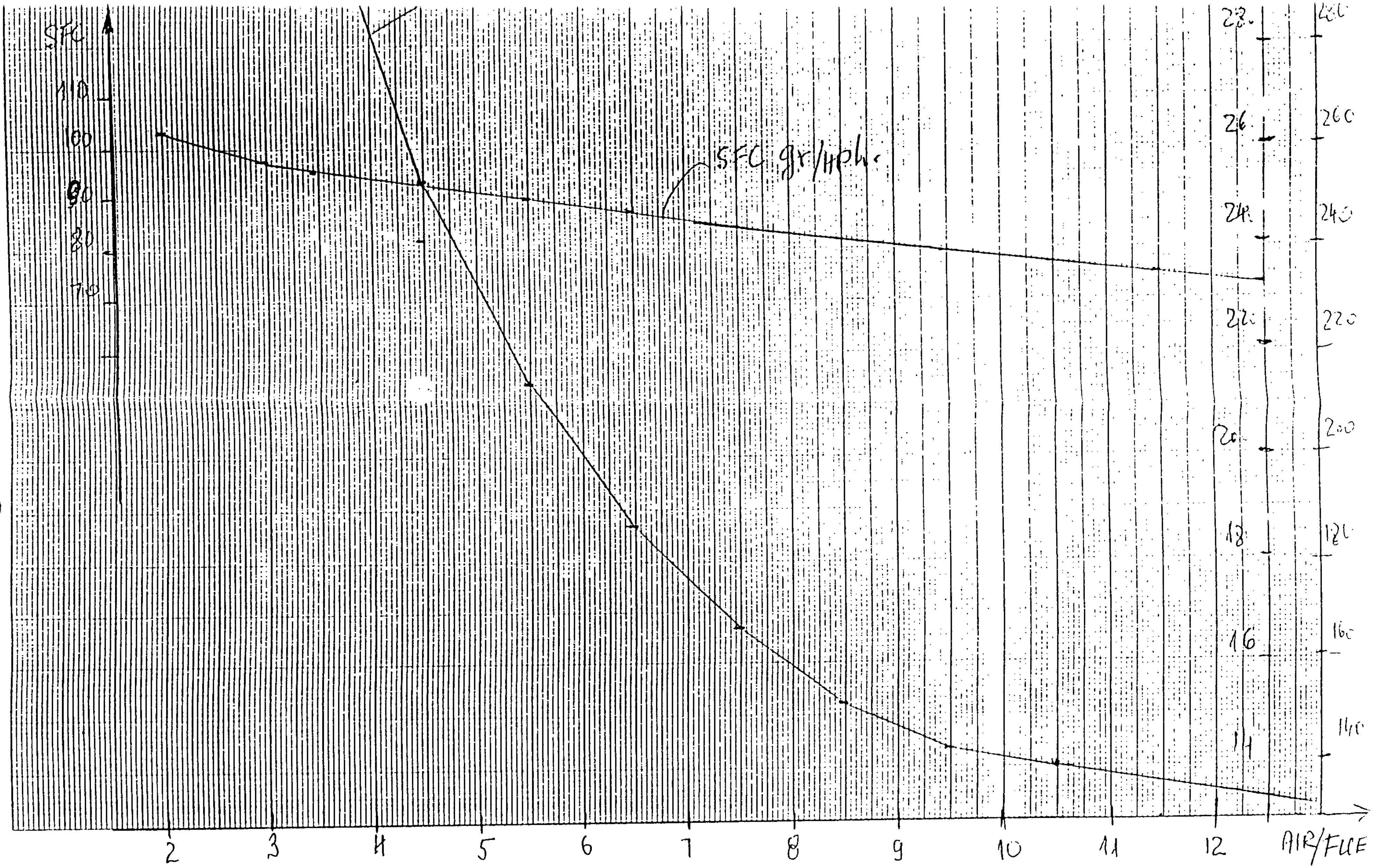


DIAGRAM 8

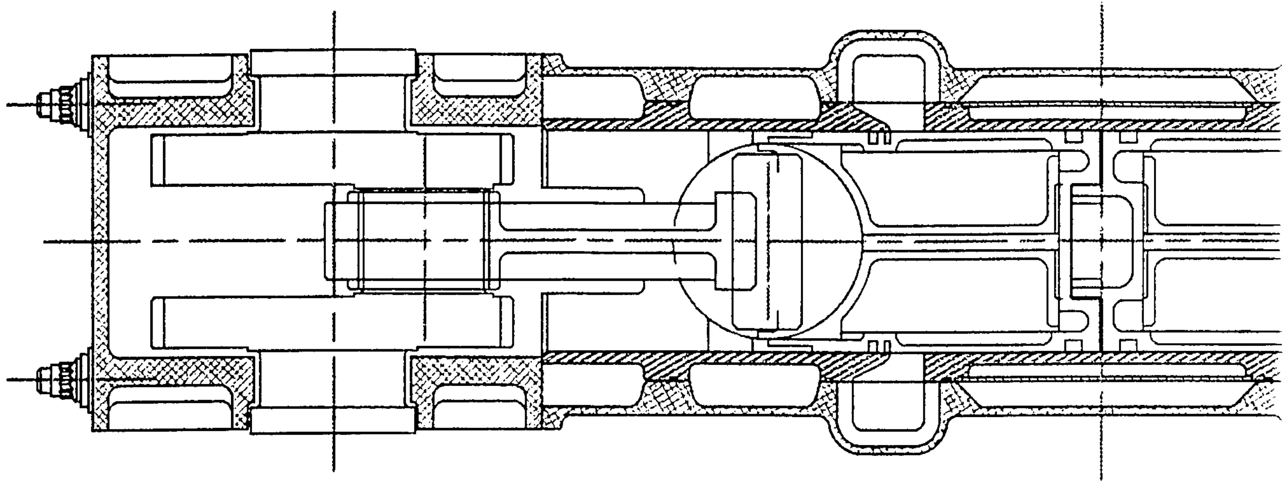
(3)

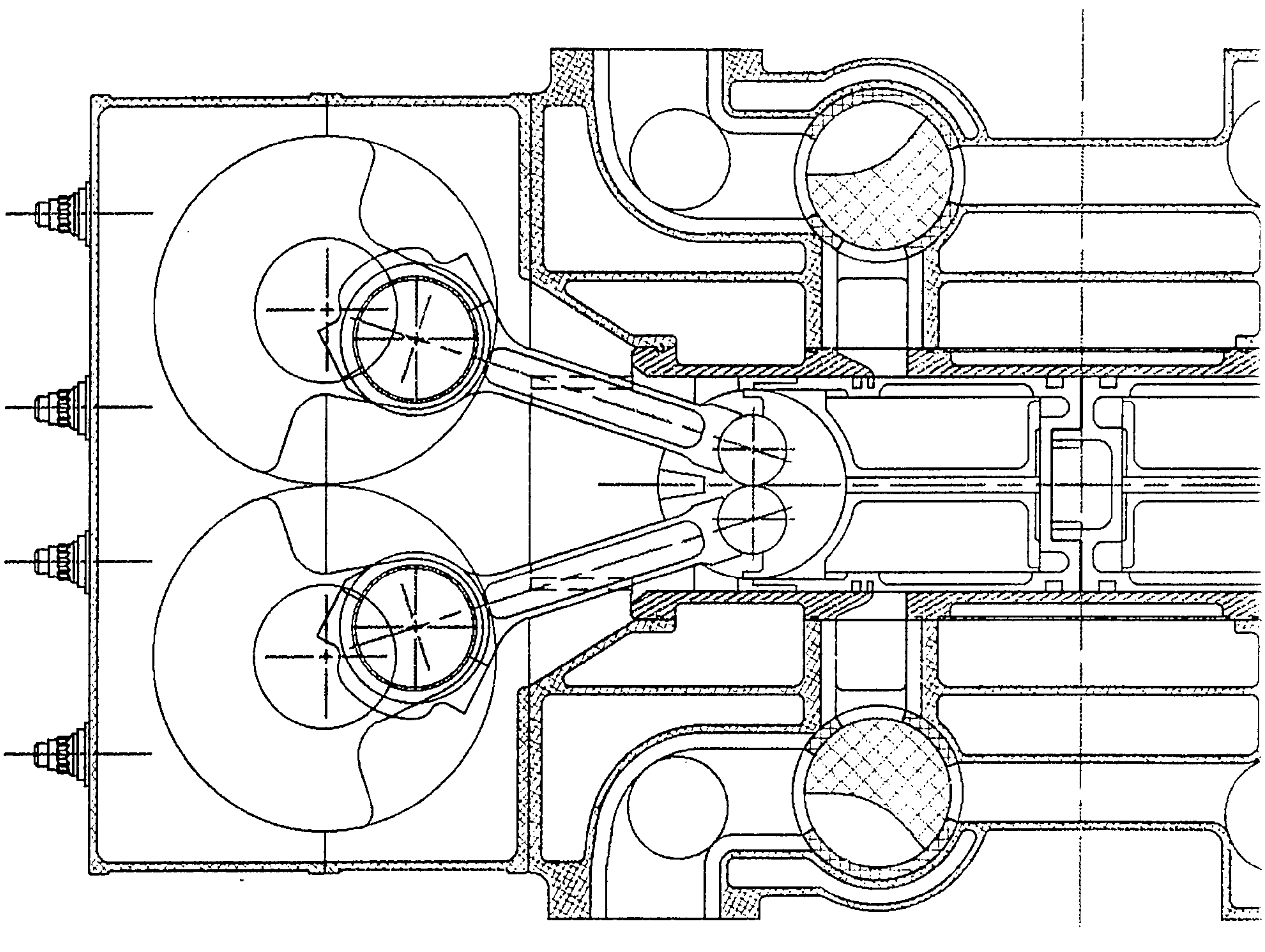
THERMO ELECTRIC COMPOUND ENGINE
MAXIMUM COMBUSTION PRESSURE = 302 BARS
2 STAGE CONSTANT SUPERCHARGING/TURBOCHARGING ps = 9 BARS
CONSTANT COMPRESSION RATIO $\sum = 13.5$
VARIABLE AIR/FUEL RATIO α =

TWO STROKE
OPPOSED PISTON, TOTAL INTAKE - EXHAUST
SEA LEVEL CONDITIONS

α	1.5	1.95	3	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
T_{comb} °k		2480	2156	2065	1942	1846	1792	1752	1721	1697	1677	1661	1647
α/T		0.6339	0.722	0.7617	0.835	0.898	0.9573	1.01	1.057	1.099	1.138	1.173	1.205
α/c		0.428	0.585	0.651	0.769	0.878	0.969	1.049	1.121	1.186	1.244	1.296	1.344
Pe kg/cm^2		52.4	35.7	31.27	25.32	21.39	18.7	16.745	15.23	14.37	13.07	12.27	11.598
SFC gr/hph		103.56	97.77	95.698	91.92	89.99	87.03	84.3	81.757	79.37	77.133	75.02	73.029
η_e		.604	.64	.65	0.681	0.695	0.719	0.74	0.765	0.788	0.81	0.834	0.857

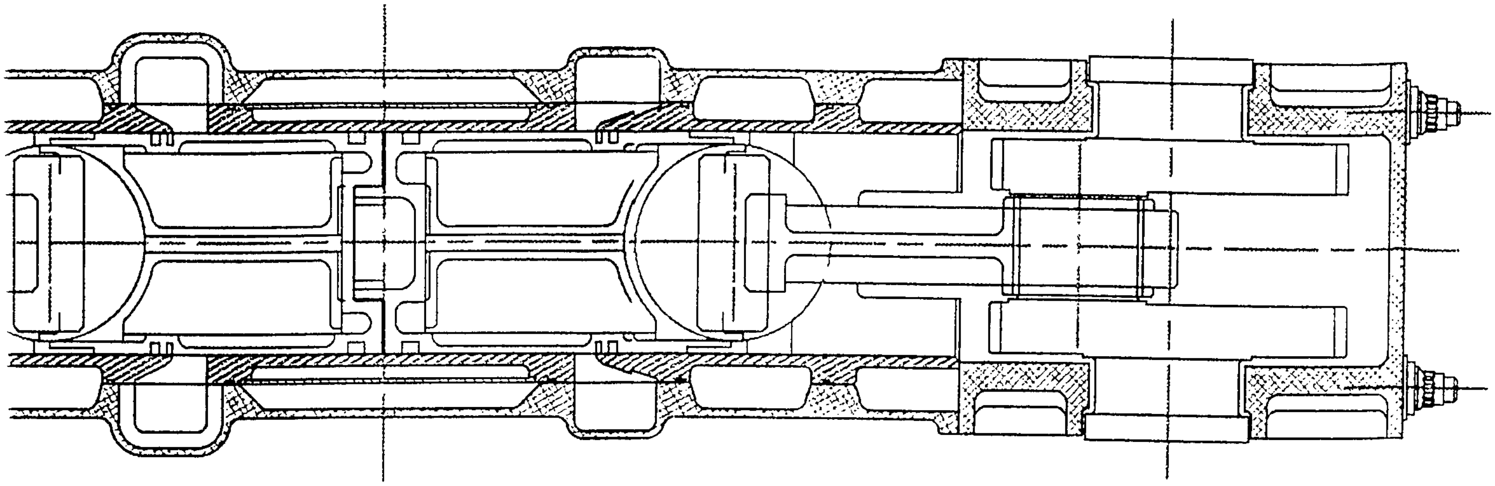
8

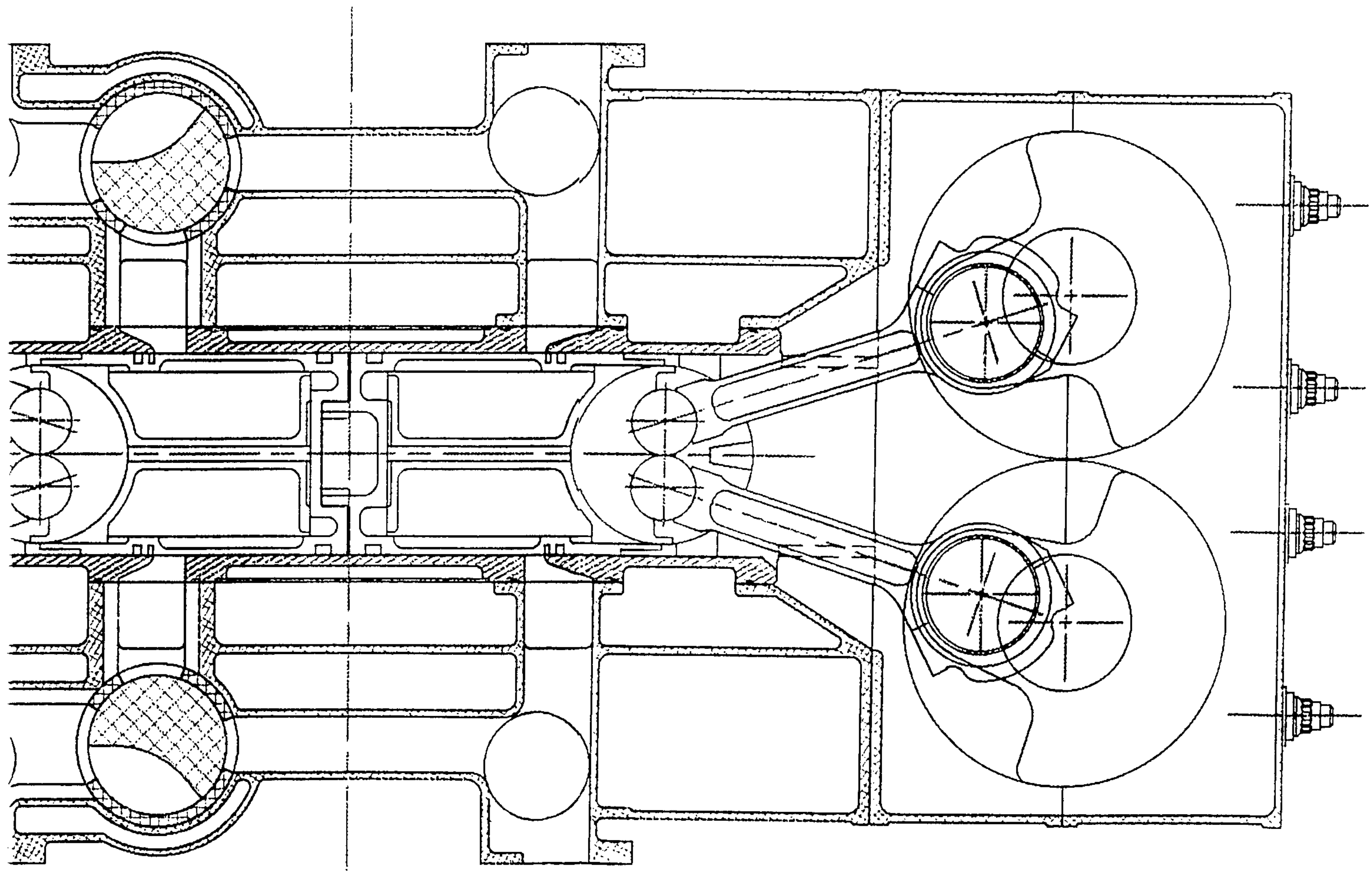




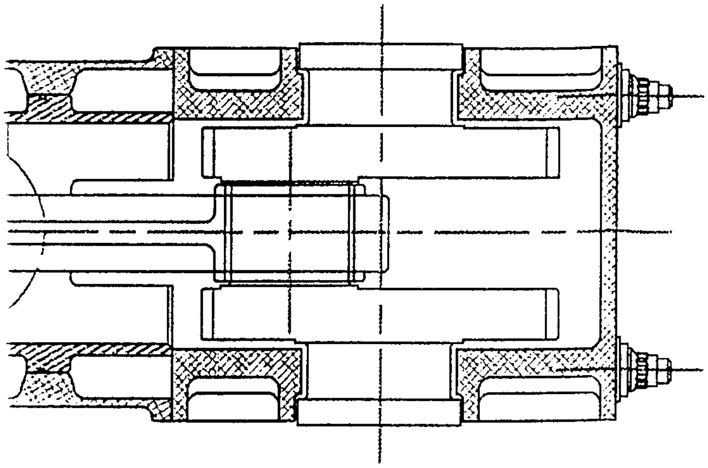
ECA 1.0 LITER MONO (
LIGHT WEIGHT C
87mm BORE, 2X 8

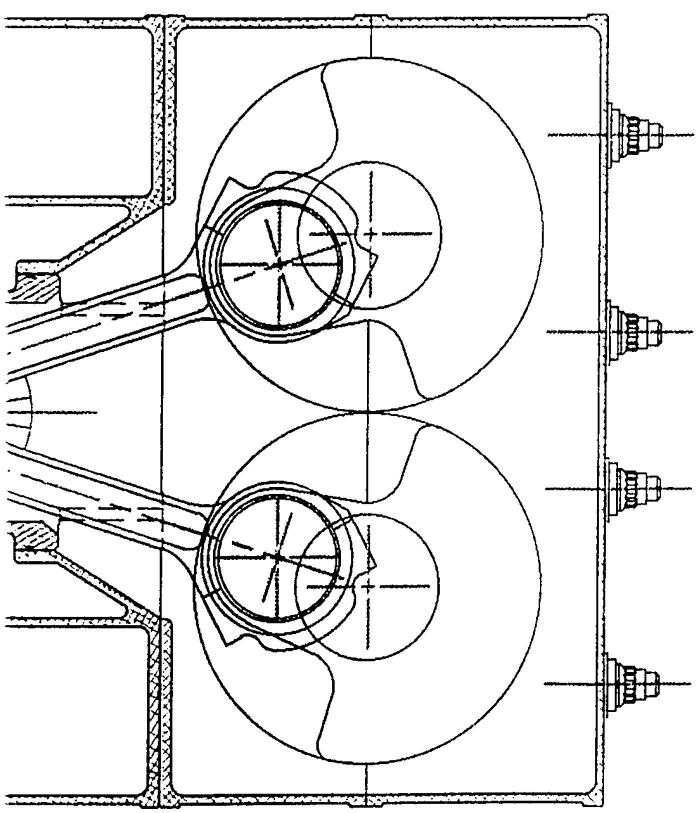
(1)

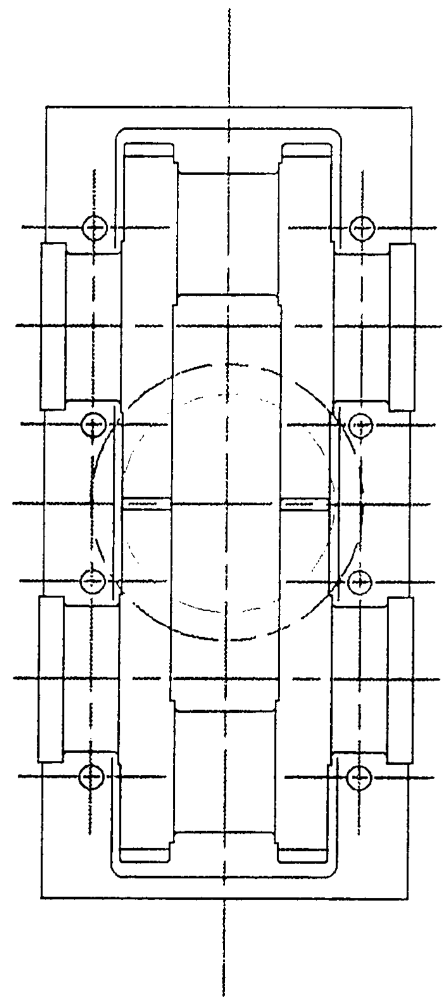




) LITER MONO CYLINDER ENGINE
GHT WEIGHT CORE MODULE
mm BORE, 2X 84mm STROKE

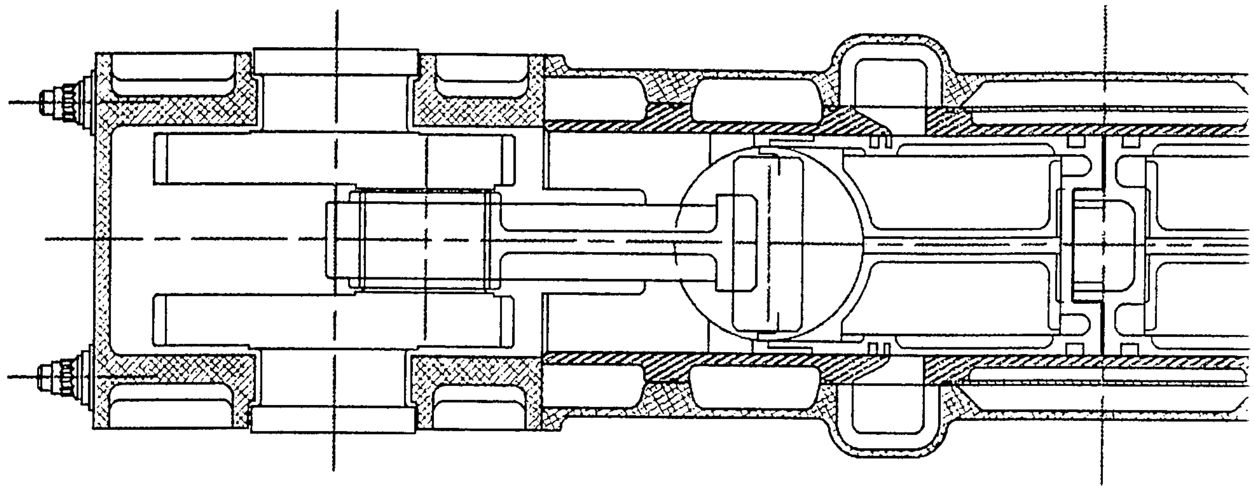


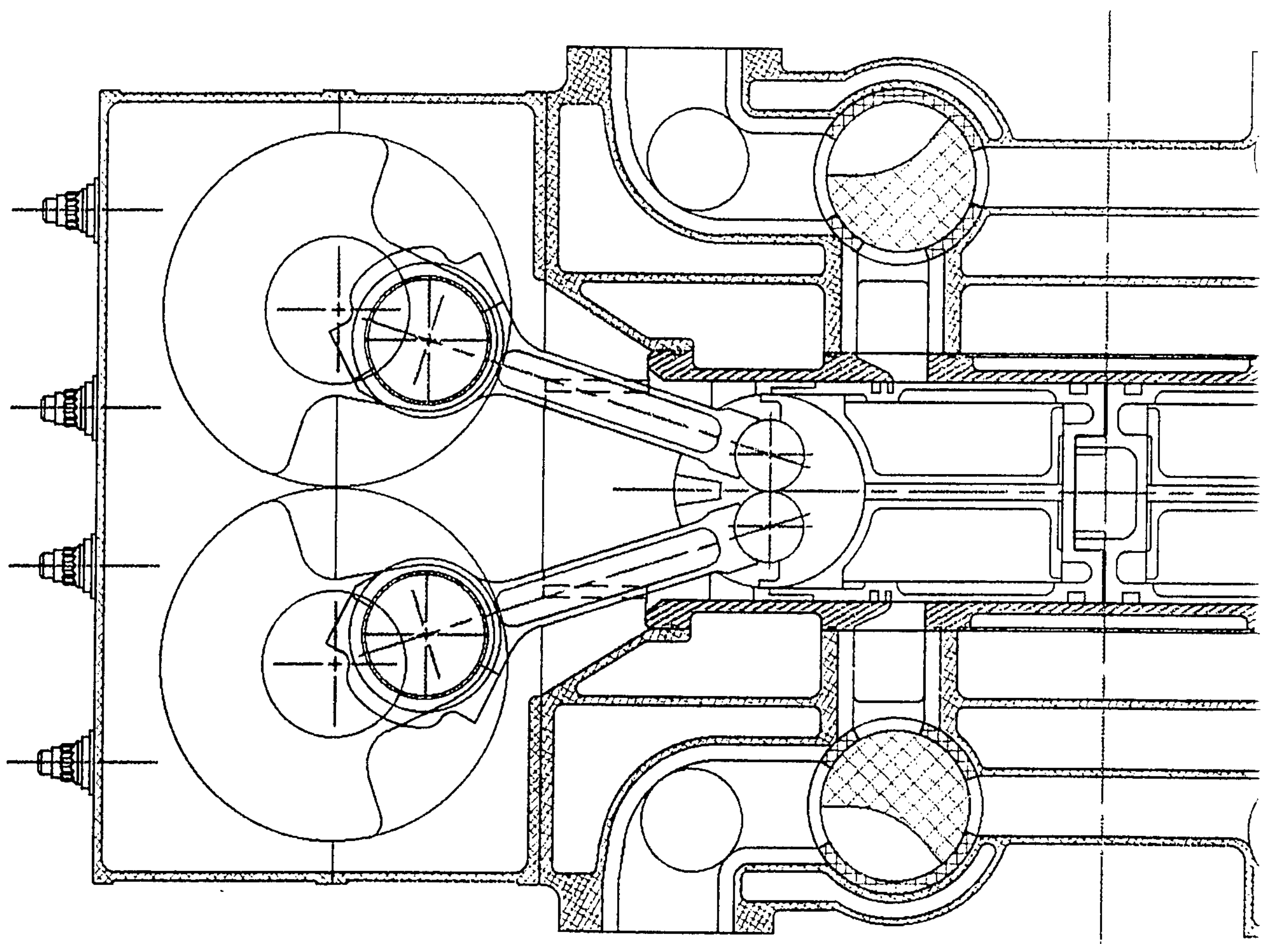




ER ENGINE
ODULE
TROKE

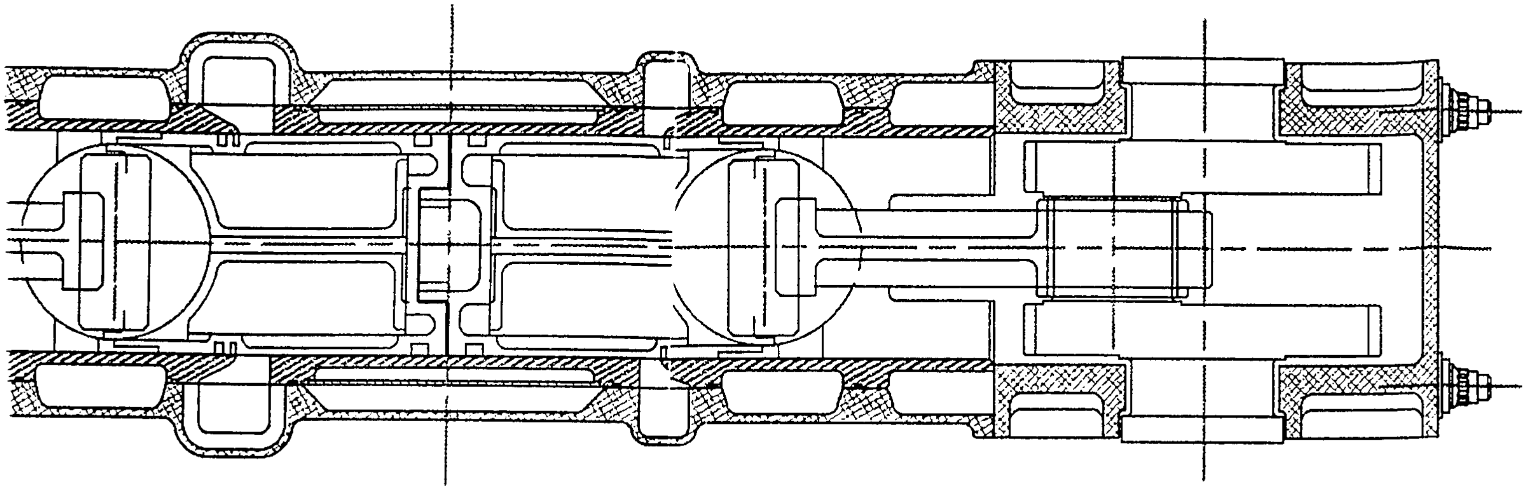
(3)

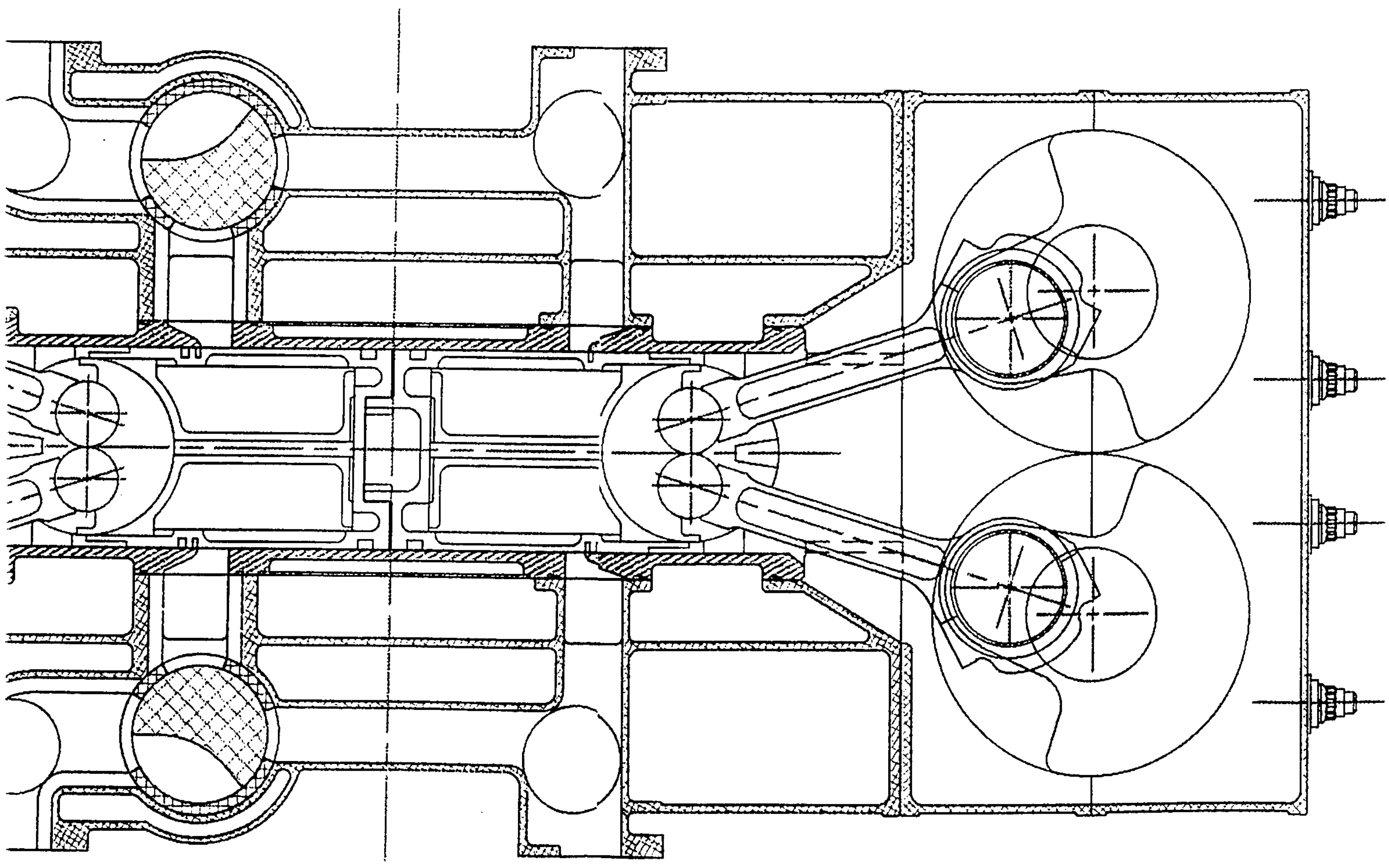




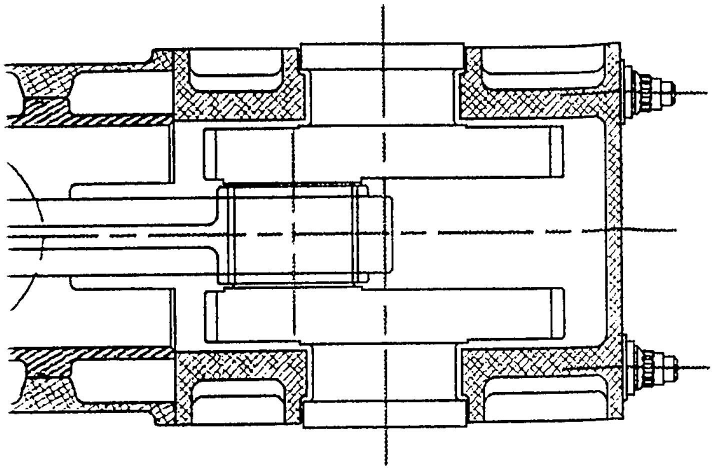
ECA 1.0 LITER MONO
LIGHT WEIGHT (
87mm BORE, 2X 8

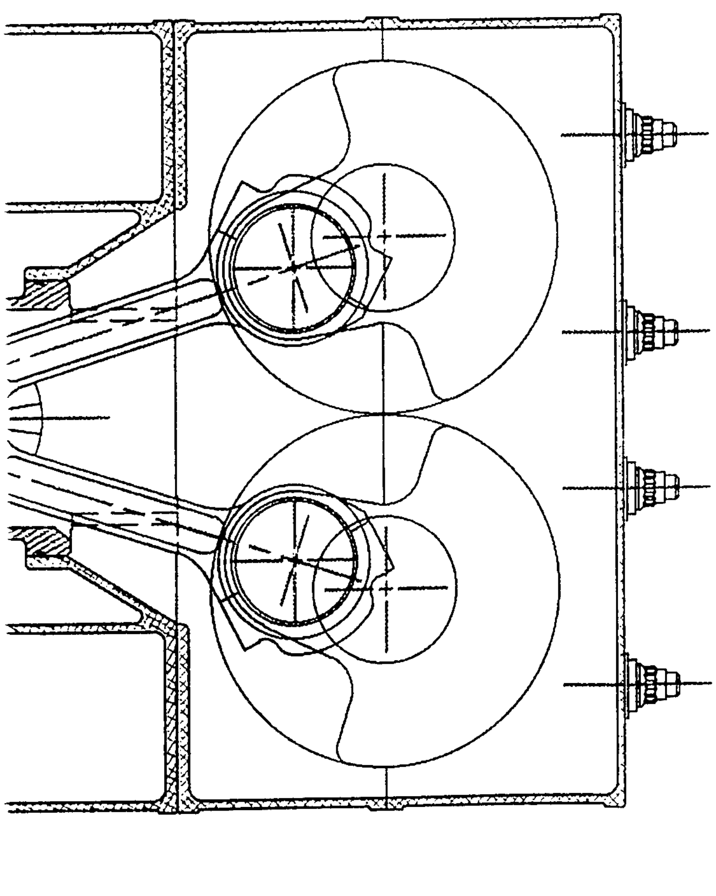
(1)

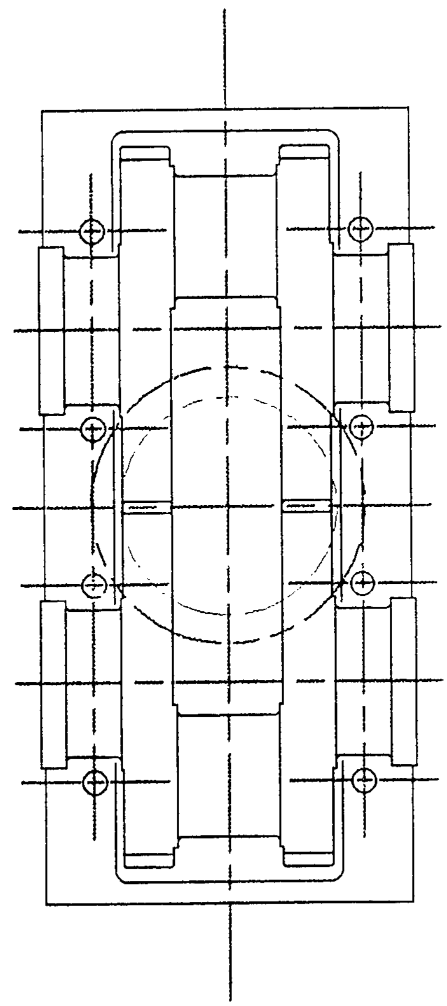




.0 LITER MONO CYLINDER ENGINE
.IGHT WEIGHT CORE MODULE
7mm BORE, 2X 84mm STROKE







DER ENGINE MODULE STROKE

③

EFFECT OF ENGINE ON TYPICAL ENDURANCE UAV (PREDATOR) PERFORMANCE

- Comparisons between engines made at identical mission conditions
  - Normal takeoff gross weight (1980 lbs)
  - Payload (450 lbs)
  - Trade fuel quantity to offset engine weight (if needed)
  - Simple Mission:
    - - - Cruise Out 500 nm (25,000 ft) at Maximum Speed
    - - - Loiter (Sea Level, 30 hp) Maximum Time
    - - - Cruise Return (25,000)

EFFECT OF ENGINE SELECTION ON TYPICAL ENDURANCE UAV (PREDATOR) PERFORMANCE

o Calculation Results[1]

Engine Manuf/ Model	Engine Weight (lb)	Fuel Avail (lb)	V (25kft)cruise (Kts)	T-out cruise (hr)	Fuel cruise (lb)	Fuel loiter (lb)	BSFC loiter (lb/hp-hr)	T loiter at 500 nm (hr)	Loiter time Ratio to ROTAX
ROTAX 912	165	650	95	5.3	208	442	0.58	25.4	1.0
ECA TECE 1.0	158	657	125	4.0	160	497	0.245	67.6	2.66
Williams 117R	260	555	112	4.5	205	350	0.95	12.3	0.48
RPI 2008	270	545	125	4.0	246	299	0.45	22.1	0.87
McCulloch	150	665	103	4.85	172	493	0.42	39.1	1.54

1

Due to simplified mission profile used in the analysis, the loiter times are approximate; however, the ratio of loiter time for any engine to the baseline ROTAX engine is a valid measure of relative improvement or reduction.

Extrap

COMPARISON OF ENGINE TECHNICAL CHARACTERISTICS

Manuf./ Model	Description	Max Pwr (hp) /BSFC @SLS (lb/hp-hr)	Loiter BSFC @ 30 hp & SLS (lb/hp-hr)	Max Pwr (hp) /BSFC @ 25Kft (lb/hp-hr)	Weight (lbs)	Technical/ Performance Summary
Williams Intl. 117R	Recuperated, single shaft turbine	120 / 0.45	0,95 .80	53 / 0.45	260	Very high engine weight, power lapse at 25k ft, and very high loiter BSFC reduces endurance 50%. Low engine performance risk, but major vehicle balance impact - redesign or 100lb ballast
Rotary Power Intl. 2008	Dual rotor Wankel, turbocharged, liquid cooled	100 / 0.53	0.45	70 / 0.45	270	Good 25k ft power & cruise speed. High system weight offsets improved part power BSFC, resulting in 13% reduction in endurance. Moderate performance risk, but major vehicle balance impact - redesign or 100lb ballast
ROTAX 912	Conventional Avgas spark ignition	80 / 0.46	0.58	35 / 0.58	165	Current Predator engine. Under powered by almost 50%, resulting in low cruise speeds (<100 kts). Part Power BSFC degrades loiter endurance.
ECA TECE	High	113 / 0.295	0.245	70 / 0.298	168	Similar weight to Rotax, but twice 25k

1.0	combustion pressure, comped,	ft power and good cruise speed. Part power SFC less than half. Endurance increased by 166%. Moderate technical risk.

COMPARISON OF ENGINE TECHNICAL CHARACTERISTICS Continued

Manuf./ Model	Description	Max Pwr (hp) /BSFC @SLS (lb/hp-hr)	Loiter BSFC @ 30 hp & SLS (lb/hp-hr)	Max Pwr (hp) /BSFC @ 25Kft (lb/hp-hr)	Weight (lbs)	Technical/ Performance Summary
McCulloch / GSE (extrap-olation)	Two cycle spark ignition to diesel conversion	100 / 0.46	0.42	44 / 0.42	150	Weight questionable. High lapse rate at 25 k ft results in low cruise speed. Possible 54% increase in endurance if claimed BSFC and weight is realized. High technical risk of gasoline to diesel conversion.

OPERATIONAL AND LOGISTIC CHARACTERISTICS

Manuf	Multi-Fuel?	Endurance at 500 nm / Ratio to Rotax hrs	Weather / wind avoidance (speed /altitude /fuel)	Altifude Capability	Detectability / Vulnerability	Failure Rate
Williams Intl 117R	yes	12.3 / 0.5	Medium	25k ft	High acoustic signature at low altitude; high IR	Low in-flight / High FOD potential on ground
Rotary Power Intl 2008RT	yes	22.1 / 0.87	Good	25k ft +	low	moderate in flight, low on ground
Rotax 912	no	25.4 / 1.0	Poor	25k ft marginal	low	moderate in flight, low on ground
ECA TECE 1.0	yes	67.6 / 2.66	Good	25k ft +	low	low to moderate in flight, low on ground
McCullough / GSE Extrap	unknown	39.1 / 1.54	Poor	unknown	low	moderate in flight, low on ground

ADDITIONAL FACTORS: IMPACT OF REALISTIC WEIGHT & BALANCE CONSIDERATIONS ON PREDATOR PERFORMANCE

- Engines weighing more than 165 lbs will alter the center of gravity (CG) aft.
  - To compensate, additional weight must be carried in the nose
  - This weight will deduct from 1980 gross takeoff weight
  - Lead ballast can be added in various areas of payload bay
  - Most favorable ballast location is forward of TSAR
    - - - Ratio of ballast to increase in engine weight increase is 0.77
  - Alternatively, payload weight may be increased, however:
    - - - Payload location is less favorable (increase approx. 0.90)
    - - - Payload volume, shape factor are issues
    - - - Mission may not require additional payloads

- For Williams engine (260 lbs)
  - Ballast required is 73 lbs and adjusted fuel load is 277 lbs
  - Endurance is 9.7 hrs (Ratio 0.38)

- For RPI engine (270 lbs)
  - Ballast required is 81 lbs and adjusted fuel load is 218 lbs
  - Endurance is 16.2 hrs (Ratio 0.64)

ADDITIONAL FACTORS: IMPACT OF INCREASING TAKE OFF GROSS WEIGHT ON PREDATOR PERFORMANCE

- Maximum Predator take off gross weight is 2100lbs (increase of 120 lbs over normal)
  - Increased gross weight primarily affects rate of climb & altitude performance
  - Also impacts structural load factor and handling qualities
  - Could allow additional fuel to be carried (up to maximum volume of fuel tank)
  - Diesel fuel is 10% denser than av gas so can carry more fuel than ROTAX if gross weight allows
  - Fuel volume limited to existing fuselage tanks (fore and aft of CG)

- Williams engine at 2100 lbs
  - Fuel weight increased to 602 lbs, approximately 397 lbs for loiter
  - Endurance increased to 13.9 hrs (Ratio 0.55)

- RPI engine at 2100 lb s
  - Fuel weight increased to 584 lbs, approximately 338 lbs for loiter
  - Endurance increased to 25.1 (Ratio 0.99)

- ECA engine at 2038 lbs
  - Fuel weight increased to 715 lbs (limited by fuel tank volume)
  - Endurance increased to 75.5 hrs (Ratio 2.97)

- McCulloch engine at 2030
  - Fuel weight increased to 715 lbs (limited by fuel tank volume)
  - Endurance increased to 43.1 hrs (Ratio 1.70)

TASK 2: FUEL INJECTOR PERFORMANCE AND OPTIONS ANALYSIS

TASK 2.1 OVERALL ECA FUEL INJECTOR DESIGNS.

BASIC CRITERIAS.

1.THE MOST IMPORTANT AND FUNDAMENTAL CRITERIA FOR THE QUALITY OF THE INJECTION SYSTEM IS THE **HIGHEST PRESSURE POSSIBLE** TO BE ACHIEVED FOR THE **HIGHEST QUALITY OF FUEL ATOMIZATIONS, FOR ALL EXISTING ENGINES AND IN SPECIAL FOR THE ULTRA HIGH PRESSURE THERMOELECTRIC ECA ENGINES.**

2.THE SHORTEST INJECTION TIME CAN PROVIDE THE BEST CONTROL OF THE COMBUSTION PROCESS, CONCENTRATED AROUND THE TOP DEAD CENTER, PRODUCING THE HIGHEST THERMAL EFFICIENCY.

3. **THE TOTAL CONTROL FOR THE MOMENT OF STARTING AND THE END** OF INJECTION, PROVIDE A TOTAL OPTIMIZATION CAPABILITY OF THE CYCLE IN RELATION WITH THE LOAD AND ROTATION

4 .**MULTIPLE PILOT AND MAIN INJECTIONS, FOR NOX, PARTICULATE AND NOISE REDUCTION**, PRODUCING THE START OF INJECTION WITH A SMALL AMOUNT OF FUEL INTO THE COMBUSTION CHAMBER IN A SPLIT SECOND BEFORE THE MAIN INJECTION. THIS PRIMING FUEL STARTS THE IGNITION AND THE MAIN FUEL INJECTION CAN BE BURNED WITHOUT IGNITION DELAY. THESE SECVENTIONAL EARLY MULTIPLE INJECTIONS CAN PREPARE **MANY STAGES OF PRE MIXINGS** , GENERATING A PROGRESSIVE **HOMOGENEOUSE LEAN MIXTURE** .

5.A **SELF INJECTION TRIANGULAR SHAPE OF INJECTION PRESSURE EVOLUTION, PROPORTIONAL WITH AND CONTEMPORARY PRESSURE COMBUSTION EVOLUTION**, IS THE MAJOR FACTOR FOR ABSOLUTE OPTIMIZATION AND CONTROL OF THE QUALITY OF THE COMBUSTION PROCESS FROM THE BEGINNING TO THE END, CONSERVING THE QUALITY OF ATOMIZATION ALONG OF THE ENTIRE COMBUSTION PROCESS, BY **CONSERVING THE PRESSURE RATIO** BETWEEN INJECTION PRESSURE AND COMBUSTION PRESSURE.

6.**UNIVERSAL ADAPTABILITY TO ANY ENGINES NEW AND EXISTENT** ON THE AFTER MARKET, WITHOUT ANY OR MAJOR MODIFICATIONS, CAPABLE TO OPERATE ON COMMON RAIL OR SELF INJECTION CONCEPT.

7.COMPLETELY FREE OF ANY AND ALL MECHANICAL TRANSMITIONS OR DRIVING SYSTEMS, AND ELIMINATING ANY AND ALL-TORSIONAL VIBRATIONS.

8.THE SELF INJECTION AND REGENERATIVE INJECTION ENERGY CAPABILITY, IS A MAJOR SOURCE FOR ELIMINATION OF THE POWER LOSES ASSOCIATED WITH THE CONVENTIONAL INJECTION SYSTEMS, TIPICAL WITH THE COMMON RAIL CONCEPT ,INCLUDING WITH THE ELECTRO HYDRAULIC (HEUI –CATERPILAR AND NAVISTAR INJECTION SYSTEM).

9.ULTRA HIGH FUEL ATOMIZATION "CONICAL VORTEX INJECTION SPRAY" FOR ABSOLUTE HOMOGENEOUS LEAN MIXTURE FORMATION.

ALL THESE CRITERIAS ARE THE CHARACTERISTICS OF THE

ECA ELECTRO HYDRAULIC SELF /COMMON RAIL

INJECTION SYSTEM.

PARAMETRIC DATA FOR THE ELECTRO HYDRAULIC

ECA SELF INJECTION (COMMON RAIL) SYSTEM

ELECTRO HYDRAULIC SELF-(COMMON RAIL) INJECTION SYSTEM FOR MONO CYLINDER TEST RIG (MTR) 1. 5 LITER/CYLINDER ,AND FOR DARO /DARPA UAV AND HEV APPLICATIONS 1.0 LITER ENGINES.

A. MAXIMUM FUEL CAPACITY PER STROKE = 384 mm 3

B. PLUNGER BORE = 7 mm

C. PLUNGER STROKE = 10mm

D. BOOSTER BORE = 25 mm

E. PRESSURE AMPLIFICATION RATIO = 12.75

F. NOMINAL RATED INJECTION PRESSURE = 3826 – 4500 BAR

G. FOR 300 - 350 BARR COMBUSTION PRESSURE

H. AVERAGE SPECIFIC FUEL CONSUMPTION:

I. ASSUMEED (CONSERVATIVE) ge = 0. 245 lb/HP. HOUR =111 gr/HP.HOUR

J. CALCULATED ge = O.22 lb/ HP.HOUR= 103 gr/HP.HOUR

K. FUEL DELIVERY/HOUR / 1000 RPM =19. 353 KG/HOUR

L. EQUIVALENT FUEL POWER/1000 RPM =19.353/O.111 =174. HP

M. FUEL POWER/2000 RPM 348 HP

N. FUEL POWER /3000 RPM 522 HP

O. FUEL POWER/ 4500 RPM 784 HP

P. RATED POWER FOR THE MTR AT 9 BAR SUPERCHARGING AND a = 1. 95 AIR/FUEL RATIO

BMEP = 50 KG/CM2 = 735 PSI

LITRIC POWER = 500 HP/ LITER AT 4500 RP

1 . 5 LITERS EFFECTIVE POWER =750 HP AT 4500 RPM

S. *TWO* ELECTRO HYDRAULIC SELF (COMMON RAIL) INJECTION UNIT PUMPS WILL DELIVER FUEL POWER EQUIVALENT 2X 784 HP = 1568 HP , ACTIVATING FOUR INJECTORS. FOR AIR CRAFT AND MILITARY APPLICATIONS A REDUNDANT FUEL SUPLIMENTARY CAPABILITY IS A MATER OF SECURITY AND SURVIVABILITY.

WITH ONE SINGLE ELECTRO HYDRAULIC PUMP THE ENGINE CAN PREZERV THE FULL POWER.

1.0 LITER DARO/DARPA UAV-HEV ENGINE USING THE SAME ONE ELECTRO HYDRAULIC PUMP WILL USE ONLY 111HP/1000 RPM FROM THE TOTAL 174HP FUEL AVAILABILITY (63%). THIS POWER/FUEL AVAILABILITY WILL BE TRIPLED AT PART LOADS OF 30 HP ON LOITER REGIME, AND CORESPONDENTLY LONGER RANGE OR LONGER TIME.

SELF OPTIMIZED INJECTION SYSTEM, FOR UNIVERSAL MILITARY AND COMMERCIAL ENGINES.

BACK GROUND.

ENGINE CORPORATION OF AMERICA, CONCEIVED AND DEVELOPED IN THE LAST 6 YEARS, A FUNDAMENTAL NEW FUEL SYSTEM TECHNOLOGY, OBJECT OF MULTIPLE PATENTED ,AND PATENT PENDING INVENTIONS, WHICH CAN PRODUCE A MAJOR IMPACT ON ALL EXISTING AND NEW ENGINES. WITH FUNDAMENTAL IMPROVEMENT OF THE EMISSION REDUCTION AND FUEL CONSUMPTION.

THE INVENTIONS RELATES TO A NEW SELF OPTIMIZED INJECTION SYSTEMS, CAPABLE TO BE TOTAL FLEXIBLE FOR PERMANENT OPTIMIZATION OF ALL THE INJECTION PARAMETERS, IN ACTUAL REAL TIME VARIATION OF THE ENGINE PARAMETERS OF LOAD, ROTATION ,EMISSION. THIS FLEXIBILITY SHOULD INCLUDE OPERATION AT VERY HIGH INJECTION PRESSURE WITH PROPORTIONAL CONTROL OF THE INJECTION PRESSURE WITH THE INTERNAL PRESSURE OF THE THERMAL CYCLE

AN ELECTRONIC CONTROL OF ALL THE PARAMETERS OF THE INJECTION. INDEPENDENT OF THE ENGINE SPEED, BUT CONTINUOUS CORRELATED BASED OF AN OPTIMIZED PROGRAM ,AND THE **TOTAL ELIMINATION OF ANY MECHANICAL DRIVING SYSTEM.**

....

THE BASIC REQUIREMENT OF ANY INJECTION SYSTEM IS TO **CONSERVE THE BEST PROPORTIONAL RELATION BETWEEN THE PRESSURE OF THE FUEL INJECTION AND THE COUNTER PRESSURE OF THE COMPRESSED AIR AND THE COMBUSTION PRESSURE IN CONTINUES VARIATION.**

BY DEFINITION A VERY HIGH PRESSURE " PROPORTIONAL DIFFERENCE " CONSERVED **ALONG ALL THE INJECTION TIME** STARTING WITH THE COMPRESSION PRESSURE AT THE BEGINNING OF THE INJECTION, AND FOLLOWED BY THE EVOLUTION OF THE COMBUSTION PRESSURE:, IS A CRITICAL CONDITION OF OPTIMIZATION AND

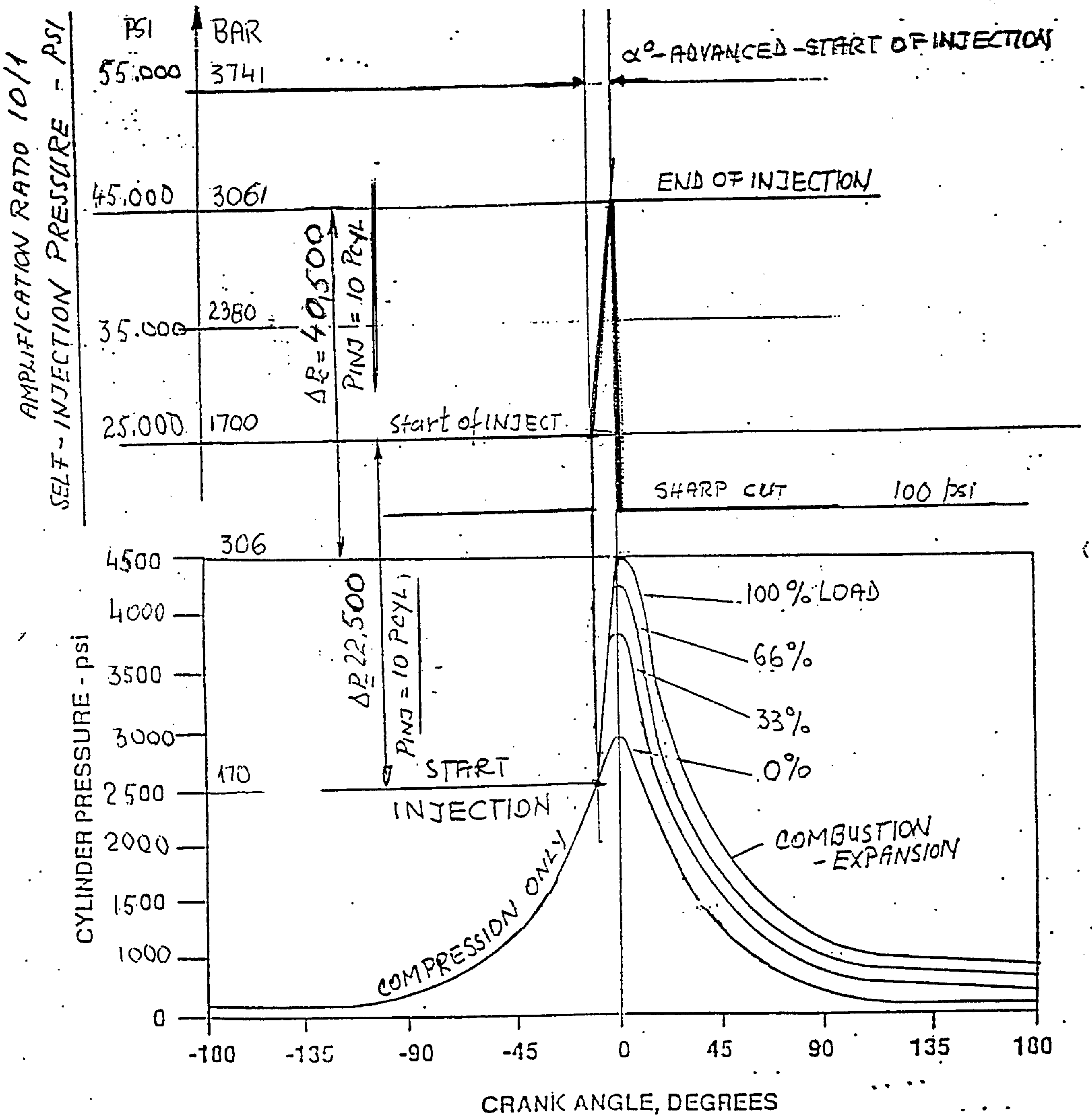
CONSERVATION OF THE ATOMIZATION OF THE FUEL SPRAY, PERMANENTLY AND AT ALL CONDITIONS.

BY DEFINITION THE LOAD , THE SPEED , THE AIR PRESSURE FUNCTION OF THE VARIABLE SUPERCHARGING LEVEL IS A PERMANENT VARIABLE CONDITION WHICH CAN HAVE A FUNDAMENTAL INFLUENCE , ON THE " INTERNAL ENVIRONMENT" EXISTENT IN THE CYLINDER IN THE TIME OF INJECTION.

NONE OF THESE CHARACTERISTICS CAN BE ACOMPLISHED BY THE ACTUAL CONVENTIONAL INJECTION SYSTEMS, WHICH SUFFER BY THEIR USE OF "FIXED GEOMETRY "MECHANICAL DRIVE SYSTEM. HENCE , THE INJECTION PRESSURE , MOMENT OF INJECTION,SPEED OF INJECTION, AND END OF INJECTION, ARE NOT RELATED DIRECTLY TO THE ACTUAL EVOLUTION OF THE PRESSURE IN THE COMPRESSION AND THE COMBUSTION CYCLE. WITH TOTAL DEPENDENCY , OF THE CAM PROFILE, THE INJECTION PROCESS IS THE REZULT OF THE LIMITATION OF THE MECHANICAL DRIVING SYSTEM , AND IS A COMPROMISE BETWEEN MECHANICAL STRESS , DYNAMICAL AND KINEMATIC LIMITATIONS AND THERMODYNAMIC NECESSITIES.

THE **MOST IMPORTANT FUNDAMENTAL INFERIORITY OF ALL THE CONVENTIONAL INJECTION SYSTEMS IS THE LOW LEVEL OF INJECTION PRESSURES** , AND THE INCAPACITY TO ACHIEVE HIGH ENGINE ROTATIONS, AND SHORT INJECTION DURATIONS.

THE **MECHANICAL CONVENTIONAL INJECTION SYSTEMS** ARE THE MOST EXPENSIVE COMPONENTS OF THE ACTUAL CONVENTIONAL DIESEL ENGINES AND RESPONSIBLE OF **MORE THAN 30% , OF THE TOTAL COST OF THE ENGINE.**



AMPLIFICATION RATIO 10/1
SELF-INJECTION PRESSURE - PSI
PSI
BAR
55,000
3741
45,000
3061
35,000
2380
25,000
1700
306
170
α° - ADVANCED - START OF INJECTION
END OF INJECTION
$\Delta P \cong 40,500$
$P_{INJ} = 10\ P_{CYL}$
Start of INJECT.
SHARP CUT
100 psi
$\Delta P \cong 22,500$
$P_{INJ} = 10\ P_{CYL}$
START INJECTION
100 % LOAD
66%
33%
0%
COMBUSTION - EXPANSION
COMPRESSION ONLY
CYLINDER PRESSURE - psi
4500
4000
3500
3000
2500
2000
1500
1000
0
-180
-135
-90
-45
0
45
90
135
180
CRANK ANGLE, DEGREES

Figure # 1

SUMMARY OF THE PROJECT.

THE NEW TECHNOLOGY IS PRODUCING AN INJECTION SYSTEM IN PERMANENT SELF OPTIMIZATION OF THE INJECTION PROCESS **CORRELATED WITH THE ACTUAL THERMAL CYCLE EVOLUTION.**

THE PROJECT IS CHARACTERIZED BY THE FOLLOWING MAIN FEATURES:

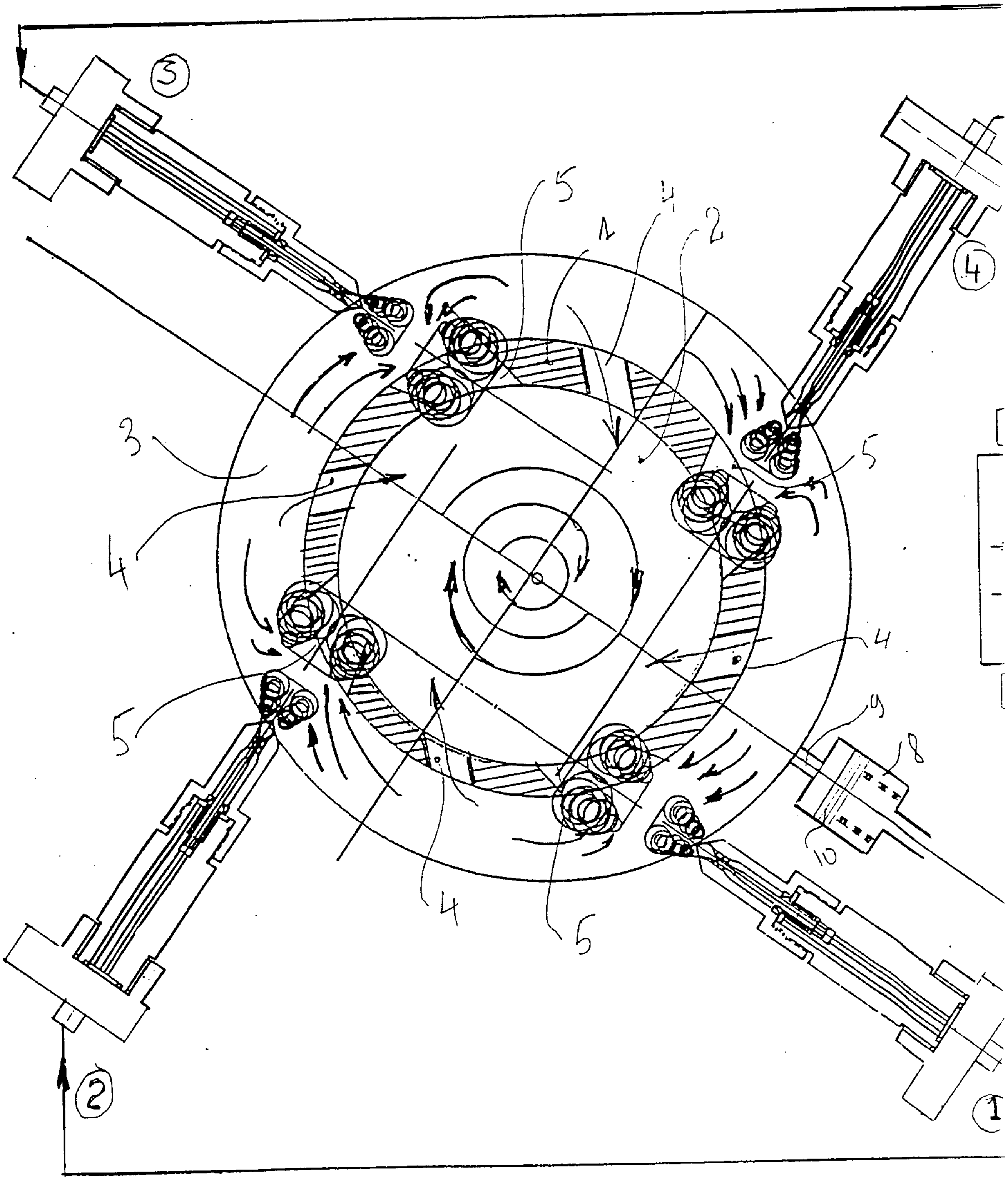
VERY HIGH PROPORTIONAL INJECTION PRESSURE , WHICH IS CONSERVING A FIX RATE OF AMPLIFICATION (10-15) TIMES THE ACTUAL PRESSURE EXISTING IN THE CYLINDER (COMPRESSION AND COMBUSTION "ALONG OF ALL THE INJECTION TIME"AND CONSERVING IN THIS WAY THE BEST CONDITION FOR THE HIGHEST QUALITY OF THE FUEL ATOMIZATION.

. MAXIMIZING AND CONSERVING OF THE FUEL SPRAY MIXING ENERGY BY A "PARALLEL TRIANGULAR AND PROPORTIONAL FUEL INJECTION RATE".

MINIMIZING THE FUEL INJECTED IN THE "IGNITION DELAY TIME " BY THE BEGINNING TRIANGULAR INJECTION RATE , AND/OR BY A "SPLIT INJECTION", ASSOCIATED WITH VERY HIGH INJECTION PRESSURE RATE OF AMPLIFICATION , CAN REDUCE DRAMATICALLY THE TOTAL INJECTION TIME.

THE COMBINATION OF REDUCED INJECTION DURATION AND ENHANCED AIR/FUEL MIXING , MAKES IT POSSIBLE TO RETARD INJECTION TIMING SEVERAL CRANK DEGREES,PARTICULARLY AT HIGH LOAD CONDITIONS, ALLOWS AN IMPORTANT REDUCTION OF NOX AND SOOT EMISSION.

ALL OF THESE COMBINED FACTORS ARE PERMITTING TO MAXIMIZE THE FUEL QUANTITY INJECTED , MIXED AND BURNED , IN THE SHORTEST ANGULAR TIME NEAR THE TOP DEAD CENTER , RESULTING MAXIMUM



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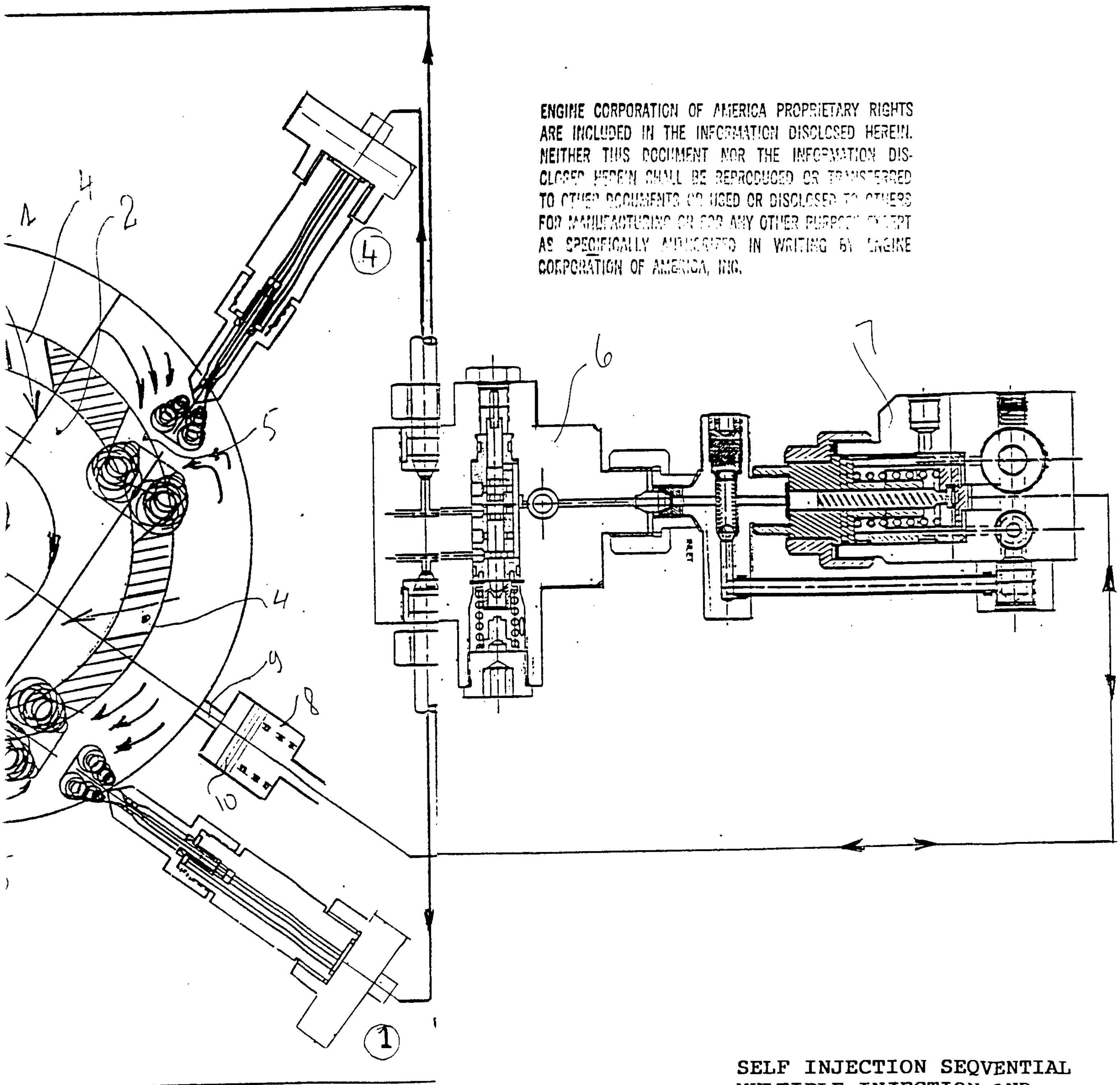
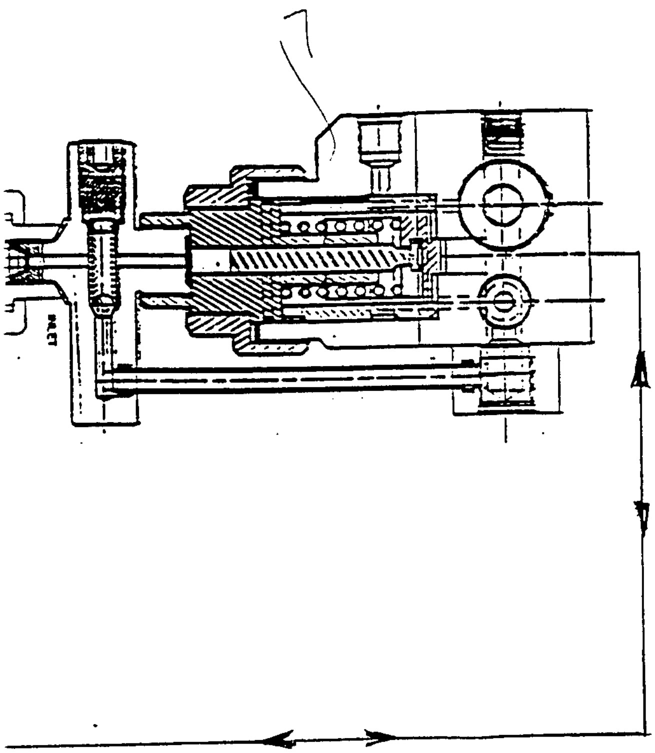


SELF INJECTION SEQVENTIAL MULTIPLE INJECTION AND TURBO COMBUSTION
FIGURE A



SELF INJECTION SEQVENTIAL
MULTIPLE INJECTION AND
TURBO COMBUSTION
FIGURE A

(3)

THERMAL EFFICIENCY AND MINIMUM SPECIFIC FUEL CONSUMPTION, WITHOUT TO COMPROMISE THE QUALITY OF COMBUSTION AND EMISSION.

INDEPENDENT INJECTION TIMING CONTROL , OF BOTH SPEED AND LOAD BUT IN DIRECT "ACTUAL RELATION WITH THE PRESSURE EVOLUTION IN THE COMPRESSION AND COMBUSTION TIME" , IS THE CONDITION TO **CONSERVE THE BEST OPTIMIZED "IDEAL" THERMODYNAMIC CYCLE** IN ALL THE FIELD OF PRACTICAL OPERATION.

ELECTRONICALLY CONTROLLED "SPLIT MULTIPLE INJECTIONS", IS REDUCING THE PARTICULATES AND THE NOX EMISSION , BY GENERATING A "HOMOGENEOUS MIXTURE ", WHICH IS PROMOTING A BETTER FUEL MIXTURE DIFFUSING AND ELIMINATING THE "HOT ISLANDS", WHICH IS THE SPECIFIC REASONS OF HIGH TEMPERATURE LOCAL CONCENTRATION, PRODUCING THE NOX EMISSION, PARTICULATES AND NOISE.

- ELECTRONICALLY CONTROLLED "TRIANGULAR INJECTION IS THE IDEAL WAY TO OBTAIN MINIMUM CONTROLLABLE FUEL DELIVERY",IMPROVING THE BRAKE SPECIFIC FUEL CONSUMPTION ,ELIMINATING THE "DIESEL KNOCK" NOISE, AND EMISSION.

SHARP CUT- OF THE INJECTION AT THE END OF THE MAXIMUM PRESSURE IS MAINTAINING VIGOROUS AIR/ FUEL MIXING ,AS FAR INTO THE COMBUSTION PERIOD, WITHOUT THE SPECIFIC DECAY OF PRESSURE , CHARACTERISTIC WITH ACTUAL CONVENTIONAL INJECTION SYSTEMS.

OUR SYSTEM IS PERMITTING TO CLOSE THE INJECTOR , ALWAYS AT

HIGHER PRESSURE THAN EXISTING IN THE COMBUSTION CHAMBER ,BY THE NATURAL INJECTION/ COMBUSTION PRESSURE AMPLIFICATION , ELIMINATING THE DANGER OF " INGESTING "OF COMBUSTED GASES IN THE INJECTOR. FIG. 1

- THE SELF INJECTION SYSTEM IS ELIMINATING COMPLETELY ANY MECHANICAL ACTUATING AND DRIVING MECHANISMS WITH CAMSHAFTS, PUSHERS ,ROCKERS , GEARS ETC.. AND IS RECOVERING ALL THE MAJORITY OF THE INJECTION ENERGY , DIRECTLY BACK IN THE COMBUSTION CHAMBER , IN THE EXPANSION TIME, WITH MAXIMUM EFFICIENCY. THIS IS A MAJOR OBSTACLE ELIMINATION WHICH PREVENTED ,CONVENTIONAL INJECTION SYSTEMS TO PRODUCE HIGH INJECTION PRESSURE.

- THE SELF INJECTION SYSTEM , OF EACH CYLINDER , IS A SELF DIAGNOSTIC SYSTEM , AND IS IN PERMANENT SELF ADJUSTING IN RELATION WITH THE OPTIMIZATION PROGRAM , MEMORIZED IN THE ELECTRONIC CONTROL MODULE (ECM) , IN PERMANENT COMPARISON WITH THE OTHER CYLINDERS, FOR MULTI CYLINDER ENGINE.

THE SYSTEM IS CONDUCTING A PERMANENT REALIGNING AND UNIFORMIZATION OF THE ENTIRE ENGINE IN REAL ACTUAL TIME, OR PRODUCING A WARNING SIGNAL IF THE CYLINDERS ARE OUT OF EQUAL ACTIONS.

THE ESSENTIAL CHARACTERISTIC OF THE NEW SELF INJECTION SYSTEM IS THE UNIVERSAL APPLICABILITY TO ANY AND ALL CATEGORIES OF ENGINES EXISTING ON THE HUGE AFTER MARKET , ON THE LINE OF ACTUAL FABRICATIONS AND TO ANY NEW ADVANCED ENGINES, WITHOUT TO IMPOSE ANY SENSIBLE

MODIFICATIONS IN THE EXISTING LINE OF ENGINE PRODUCTIONS.

ON THE CONTRARY IS OFFERING THE POSSIBILITY TO REDUCE ESSENTIALLY THE **COST FOR THE NEW ENGINES IN A PROPORTION OF AT LEAST OF 30%,** BY THE TOTAL ELIMINATION OF THE INJECTION PUMPS, WITH MULTIPLE CYLINDERS , AND ALL THE MECHANICAL DRIVING SYSTEMS INCLUDING CAMSHAFTS , GEARS, PUSHERS ,ROCKERS, AND THE ENTIRE MECHANICAL TRANSMISSION SYSTEM.

THE UNIVERSAL APPLICABILITY , IS THE WAY TO PENETRATE IN A VERY SHORT TIME THE EXISTING HUGE AFTER MARKET OF ALL CATEGORIES OF DIESEL AND SPARK IGNITED DIRECT INJECTION ENGINES , WITH THE IMMEDIATE MAJOR IMPACT TO THE EMISSION REDUCTION AND AN ESSENTIAL REDUCTION OF THE FUEL CONSUMPTION OF ALL CONVENTIONAL AND NEW ENGINES.

ULTRA HIGH PRESSURE "ECA COMMON RAIL" ALTERNATIVE

BACK GROUND

THE EXISTING COMMON RAIL INJECTION SYSTEMS ARE ASSOCIATED WITH A FUNDAMENTAL AND ESSENTIAL LIMITATION OF THE INJECTION PRESSURE NOT MORE THAN 1300 -1500 BAR. THIS LIMITATION IS THE REZULT OF THE INCAPACITY OF THE EXTERNAL PUMP TO PRODUCE AND TO TRANSMIT THROUGH LONG PIPES THE HIGH PRESSURE TO THE MULTI CYLINDERS ENGINES .

ASSOCIATED WITH THIS SSENTIAL LIMITATION IS THE "HELMHOLTZ EFFECT " OF PRESSURE WAVE GENERATION AND INTERFERENCE BETWEEN THE ACTUAL INJECTION PRESSURE , IN THE MOMENT OF INJECTIONS, OF DIFERENT INJECTORS. THE FRECVENT REZULT IS BIG CYLINDER COMBUSTION VARIATIONS, VIOLLENT TORQUE OSCILATIONS , AND VIBRATIONS AT DIFFERENT CRITICAL SPEEDS .

IN THE TIME **BETWEEN INJECTIONS THE COMMONRAIL AT 1500 BAR IS LOOSING ALL THE HYDRAULIC ENERGY THROUGH RELIEF VALVES WHICH ARE**

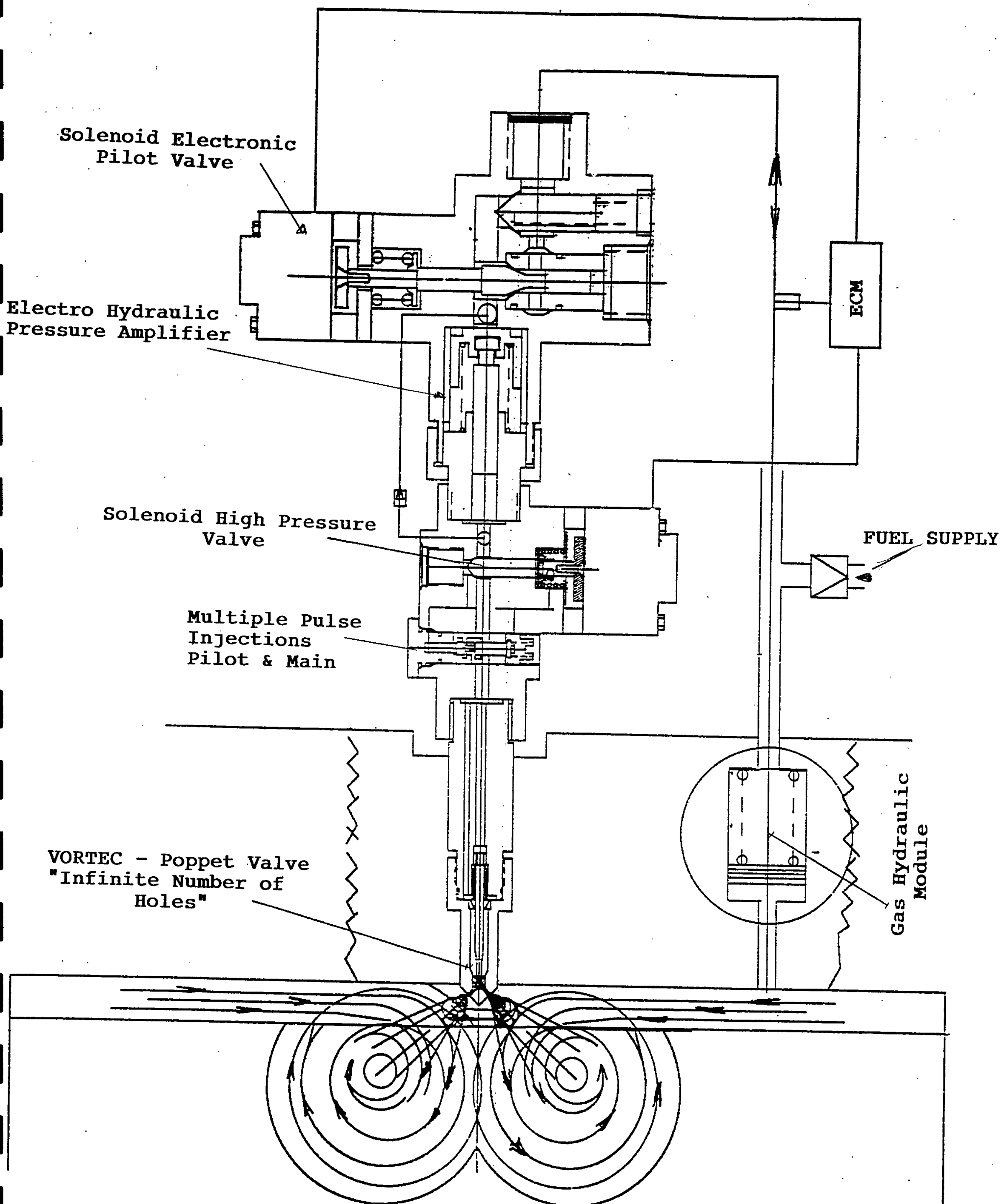

Solenoid Electronic
Pilot Valve
Electro Hydraulic
Pressure Amplifier
ECM
Solenoid High Pressure
Valve
FUEL SUPPLY
Multiple Pulse
Injections
Pilot & Main
Gas Hydraulic
Module
VORTEC - Poppet Valve
"Infinite Number of
Holes"

FIGURE 2

ELIMINATING THE SURPLUS OF HIGH PRESSURE FLUID AND BY CONSECVENCE THE BIG ENERGY ASSOCIATED WITH THIS "HEMORAGY".

THE MAGNITUDE OF PERMANENT ENERGY LOSS IS THE MOST IMPORTANT REASON OF INJECTION PERSSURE LIMITATIONS, AND A PERMANENT HIGHER SPECIFIC FUEL CONSUMPTION.

ECA COMMON RAIL ULTRA HIGH PRESSURE ALTERNATIVE IS ELIMINATING TOTALLY THESE DEFECTS BY THE FOLLOWING REASONS AND CARACTERISTICS:

1. ECA ULTRA HIGH PRESSURE IS GENERATED **INSIDE OF THE UNIT INJECTOR**, NOT IN THE EXTERNAL COMMON HYDRAULIC PUMP AND THE PRESSURE AND THE MOMENT OF INJECTION AND THE END OF INJECTION OF EACH INJECTOR , IS TOTALLY ISOLATED FROM THE OTHER INJECTORS.

2. **ECA COMMON RAIL PRESSURE SUPPLIED BY THE EXTERNAL COMMON PUMP** IS
3. **10- 15 TIMES LOWER, THAN** THE ACTUAL COMMON RAIL PRESSURE OF THE EXISTING
4. CONVENTIONAL SYSTEMS . THE REZULT IS PRPOPRTIONAL LOWER ENERGY CONSUMPTION FOR DRIVING ECA COMMON RAIL SYSTEM.

THE MOST IMPORTANT CARACTERISTIC OF ECA **COMMON RAIL ULTRA HIGH PRESSURE INJECTION SYSTEM IS THE FACT THAT IS IDENTIC WITH THE SELF INJECTION SYSTEM USING THE SAME UNIT PUMP INJECTOR** , AND A COMMON PUMP AT LOW RESSURE (200 BAR) INSTEAD 2000 BAR SPECIFIC FOR CONVENTIONAL SYSTEMS.

WITH DIRECT RELATION WITH THE DARO/ DARPA , THERMOELECTRIC COMPOUND ENGINE PROGRAM, IN WHICH THE ULTRA HIGH PRESSURE COMPRESSION AND COMBUSTION THERMAL CYCLE, IS REQUIRING AN ADEQUATE ULTRA HIGH PRESSURE INJECTION SYSTEM, ECA IS PROPOSING THE SELF INJECTION SYSTEM TO BE THE FIRST MAJOR PART OF THE DARO/DARPA PROGRAM.

WITH THE UNIVERSAL DUAL APPLICABILITY FOR ANY AND ALL MILITARY ENGINES,

AND ALL THE COMMERCIAL ENGINES, THE COMBINED GOVERNMENT AND PRIVATE MATCHING FUNDING OF THE PROGRAM, IS A SOLID FOUNDATION FOR A REALISTIC MILITARY AND COMMERCIAL GENERAL APPLICABILITY.

E.C.A SELF INJECTION DESCRIPTION AND FUNCTIONALITY.

THE "SELF INJECTION " NOTION IS THE REZULT OF THE FUNDAMENTAL DIFERENCIES BETWEEN THE CONVENTIONAL INJECTION SYSTEMS , WHICH ARE ACTIVATED FROM AN EXTERNAL ENGINE SOURCE OF POWER , AND A MECHANICAL SYSTEM OF TRANSMISSION, FORMED FROM GEARS , CHAINES , BELTS , CAMSHAFTS, ROCKERS, PUSHERS, MULTIPLE CYLINDERS HIGH PRESSURE PUMPS, HIGH PRESSURE HYDRAULIC LINES, AND FINALLY INDIVIDUAL INJECTORS. ALL OF THESE ARE ELIMINATED BY OUR ECA "SELF INJECTION SYSTEM" WHICH IS ACTIVATED DIRECTLY FROM THE PRESSURE EVOLUTION IN THE ENGINE CYLINDER. FIG.2

BY DEFINITION ECA SELF INJECTION SYSTEM , IS A UNIC ELEMENT OF PUMP/INJECTOR PER CYLINDER, ACTIVATED BY AN INDIVIDUAL GAS/HYDRAULIC MODULE, IN PERMANENT CONTACT WITH THE COMBUSTION CHAMBER OF THE ENGINE, THROUGH A SMALL COMUNICATION TUBE. INSIDE OF THE GAS HYDRAULIC MODULE IS A SMALL "FREE PISTON", RECEIVING ON ONE SIDE THE GAS PRESSURE WHICH IS INTHE CYLINDER "IN REAL TIME", AND ON THE OTHER SIDE TRANSMITING THE SAME PRESSURE , IN THE OIL/HYDRAULIC CYLINDER , CONNECTED WITH AN OIL TUBE WITH THE ELECTRO HYDRAULIC AMPLIFIER UNIT PUMP/INJECTOR.

THE ELECTRO HYDRAULIC AMPLIFIER CYLINDER IS RECEIVING IN THE PRIME CYLINDER THE HYDRAULIC PRESSURE EQUAL WITH THE REAL PRESSURE IN THE ENGINE CYLINDER, AND IS TRANSMITING THE HYDRAULIC FORCE TO A SMALL PLUNGER WHICH IS SITUATED IN THE INJECTION CYLINDER. THE AREA OF THE INJECTION PLUNGER IS 10--15

TIMES SMALLER THEN THE AREA OF PISTON IN THE PRIME CYLINDER , REZULTING A PRESSURE AMPLIFICATION FOR THE INJECTION, IN THE SAME PROPORTION.

THE AMPLIFIER CYLINDER, IS PROVIDED WITH A SOLENOID ELECTRONIC CONTROLLED PILOT VALVE, AND THE INJECTION CYLINDER IS PROVIDE WITH A SOLENOID HYGH PRESSURE VALVE.

THE UNIT ELECTRO HYDRAULIC AMPLIFIER PUMP CAN BE CONNECTED WITH ANY CONVENTIONAL OR NEW INJECTORS.

ECA NEW INJECTORS CAN PROVIDE PILOT AND MULTIPLE "PULSE INJECTIONS" WHICH CAN DISTROI AND ELIMINATE THE CONVENTIONAL " HOT ISLAND" OF THE INJECTED PLUME, ELIMINATING THE MAJOR SOURCE OF EMISSION, BY THE REACH MIXTURE , CARACTERISTIC FOR THE CONVENTIONAL DIESEL INJECTORS.

A SPECIAL CONFIGURATION OF ECA INJECTORS IS PROVIDED WITH THE EQUIVALENT " INFINITE NUMBER OF HOLES" GENERATING HOLLOWS CONIC INJECTIONS ELIMINATING TOTALLY THE CENTRAL REACH MIXTURE , RESPONSABLE FOR ALL THE EMISSIONS.FIG.3

ALL THESE UNIC CARACTERISTICS ,IS FORMING AN ABSOLUTE SUPERIORITY, OVER ANY AND ALL CONVENTIONAL INJECTION SYSTEMS.

DEPENDING OF THE ENGINE CONFIGURATION, EACH AND ALL CYLINDERS ARE ASSOCIATED WITH A CENTRAL UNIC ELECTRONIC CONTROL MODULE, WHICH IS ABLE IN "REAL TIME " CYCLE BY CYCLE , TO ACTIVATE, TO COMAND AND TO CONTROL EACH CYLINDER , TO DIAGNOSE ANY AND ALL DEVIATIONS . FROM AN ABSOLUTE PERFECT UNIFORMIZATION OF ALL CYCLES AND CYLINDERS,AND TO COMMAND AN INSTANT "EQUALIZATION".

ECA "SELF INJECTION TECHNOLOGY" ,HAVE A UNIC " TRIANGULAR "EVOLUTIVE PRESSURE INJECTION RATE ,(FIG.1) WHICH IS GENERATING A CONSTANT AMPLIFICATION OF THE INJECTION PRESSURE , STARTING WITH INITIAL 10...15 TIMES OF THE COMPRESSION PRESSURE AND FINISHING ,WITH THE SAME RATE OF AMPLIFICATION THE COMBUSTION PRESSURE. CONSERVING THE INJECTION PRESSURE AMPLIFICATION FROM THE BEGINING OF COMBUSTION UNTIL THE END OF COMBUSTION AT ULTRA HIGH PRESSURE OF 30,000- 50,000 PSI.

THE END OF INJECTION IS PRODUCED BY THE DE-ENEGIZING OF THE SOLENOID (FIG.2) COMANDING THE HIGH PRESSURE VALVE , WHICH WILL OPEN THE INJECTION CYLINDER, PRODUCING A SHARP CUT OF THE INJECTION. IN THIS WAY IS ELIMINATING ANY POTENTIAL POST OR LATE INJECTIONS , WHICH IS THE MAJOR DEFECT OF THE CONVENTIONAL INJECTION SYSTEMS , AND THE SOURCE OF INTENSE EMISSION , SMOKE GENERATION AND HIGH FUEL CONSUMPTION .

MULTIPLE SECVENTIAL INJECTION SYSTEM FOR OPPOSED PISTON ECA ENGINES DARPA / DARO ,MTR, UAV AND HEV APPLICATIONS.

THE OPPOSED PISTON ECA ENGINE , HAVE A SPECIFIC CONFIGURATION OF THE COMBUSTION CHAMBER CREATED BETWEEN THE TWO OPPOSED PISTONS , CARACTERIZED BY A CENTRAL COMBUSTION CHAMBER REZULT OF THE CONJUNCTION OF A SPECIAL CROWN (1) ATTACEHED TO ONE PISTON AND THE CORRESPONDING RECESSED CENTRAL COMBUSTION CHAMBER (2) LOCATED IN THE SECOND OPPOSED PISTON.(FIG A) AND (FIG B)

BEFORE THE END OF THE COMPRESSION STROKE , APROXIMATIVE 30 DEGREE BEFORE THE TOP DEAD CENTER, THE CROWN (1) OF ONE PISTON IS SEPARATING THE COMBUSTION CHAMBER IN TWO REGIONAL WORKING CHAMBERS , ONE SITUATED ON THE

OUTSIDE PERIFERY (3) OF THE CROWN AND THE SECOND (2) IN THE CENTER OF THE SECOND PISTON.

BY PENETRATING THE CIRCULAR CROWN (1) IN THE CENTRAL COMBUSTION CHAMBER (2), THE PERIFERICAL AIR (3) IS FORCED TO BE INJECTED TANGENTIALLY THROUGH, A NUMBER OF PORTS(4) ,IN THE CENTRAL COMBUSTION CHAMBER,(2) CREATING A VERY INTENSIVE TANGENTIAL AND FINAL SPIRAL HIGH SPEED AIR MOVEMENT.

0NE ,TWO ,THREE,OR FOUR ECA SPECIAL FUEL INJECTORS, ARE DISTRIBUTED ALSO TANGENTIALLY IN CORRESPONDENCE WITH THE NOZZLE PORTS (5). THE INJECTORS ARE CONNECTED WITH A SELF DISTRIBUTION FUEL DEVICE (6). THE HIGH PRESSURE MODULE (7) IS THE SOURCE OF EACH INJECTION PULSE, WHICH IS DISTRIBUTED SECVENTIALLY TO THE FOUR INJECTORS IN A SECVENCE 1,2,3,4,/PER CYCLE AND ROTATION . EACH INJECTORS IS PRODUCING TWO INJECTIONS "PILOT AND MAIN" REZULTING AT LEAST 8 INJECTIONS PER CYCLE . ALL OF THEM ARE TOGHETER ON NO MORE THAN 15—20 DEGREE OF TOTAL CRANK ANGLE, CONTEMPORARY WITH THE INTERCONJUNCTION OF THE OPPOSED PISTONS (CROWN (1) AND CHAMBER (2)).

THE INJECTED FUEL IS ACCELERATED IN A **HIGH SPEED VORTEX** ,EXPLOSIVE ATOMIZED JET OF DOUBLE INJECTIONS ,(PILOT AND MAIN) THROUGH THE NOZZEL PORTS (5), AND TOGHETER WITH THE AIR INJECTON, IS FORMING AN EXTRAORDINARY SUPER MIXED AIR AND FUEL TO THE LEVEL OF **TOTAL HOMOGENEOUS MIXTURE.**

ALL THE SYSTEM IS SELF ACTIVATED BY THE GAS HYDRAULIC ACTUATOR (8) WHICH IS CONNECTED THROUGH THE CHANEL 9 WITH THE COMBUSTION CHAMBER, AND IS PRMANENTLY TRANSFERING THE GAS PRESSURE EVOLUTION TO THE OTHER SIDE OF THE " FREE " PISTON (10), AND CREATING A FUEL ACTUATION PRESSURE EQUAL WITH THE ACTUAL PRESSURE EXISTENT IN THE COMBUSTION CHAMBER. THIS FUEL PRESSURE IS TRANSFERRED IN THE HIGH PRESSURE MODULE 7, AND **AMPLIFIED THE INJECTION**

PRESSURE IN A PROPORTION 0F 12—15 TIMES THE GAS PRESSURE ACTUALLY EXISTENT IN THE COMBUSTION CHAMBER.

THE ASSOCIATED ACTIONS OF:

SECVENTIONAL 8 PILOT AND MAIN INJECTIONS, TANGENTIALLY ACCELERATED , BY SELF AIR TANGENTIAL INJECTIONS , ULTRA HIGH SPEED VORTEX ATOMIZATION, ULTRA HIGH PRESSURE SELF INJECTION AND THE ABSOLUTE HOMOGENIZATION OF THE FINAL AIR/FUEL MIXTURE, WILL BE THE ABSOLUTE SOLUTION FOR *AN IDEAL CLEAN COMBUSTION* **WITH ZERO EMMISSION AND MULTI FUEL CAPABILITY.**

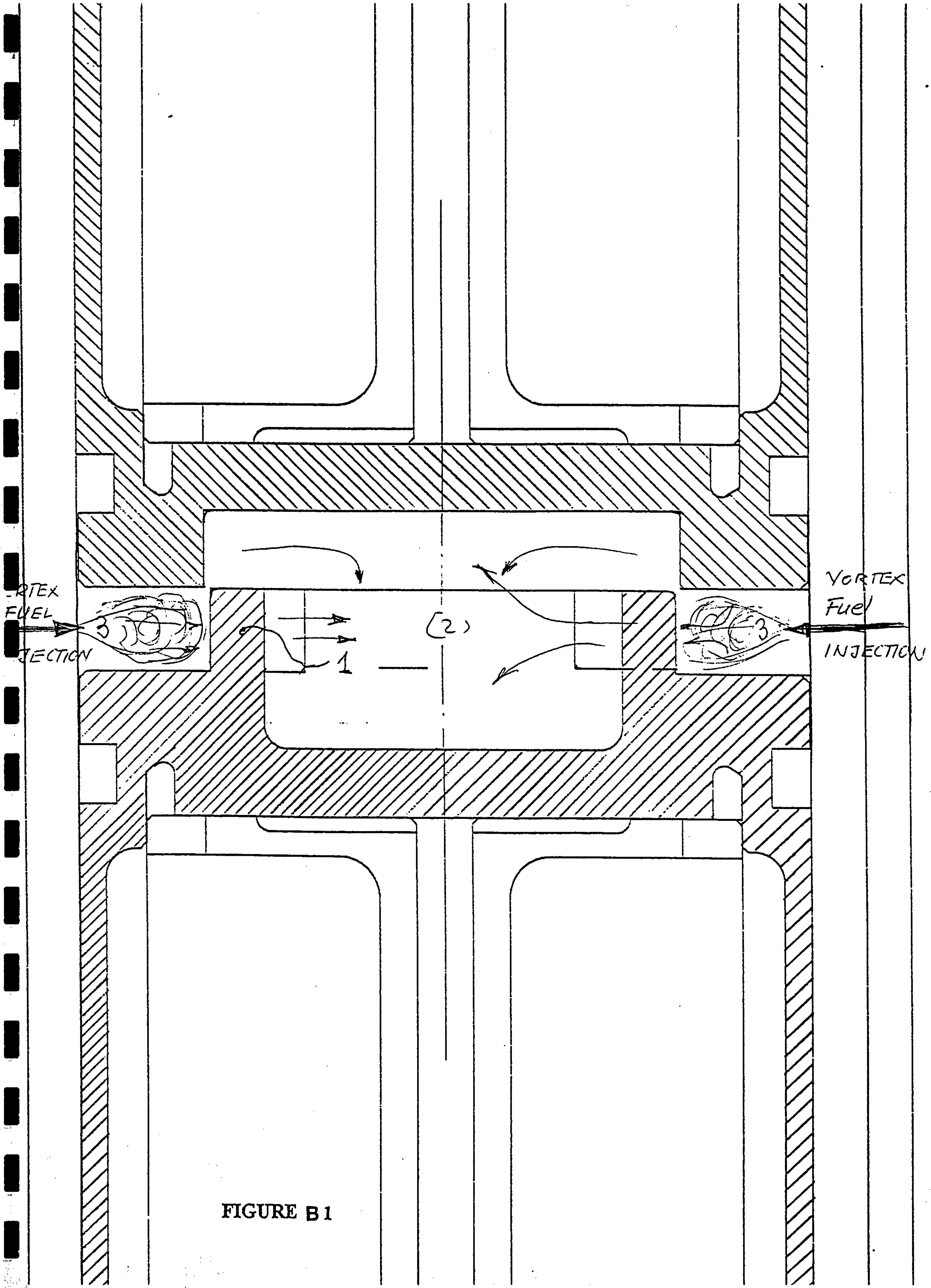


FIGURE B1

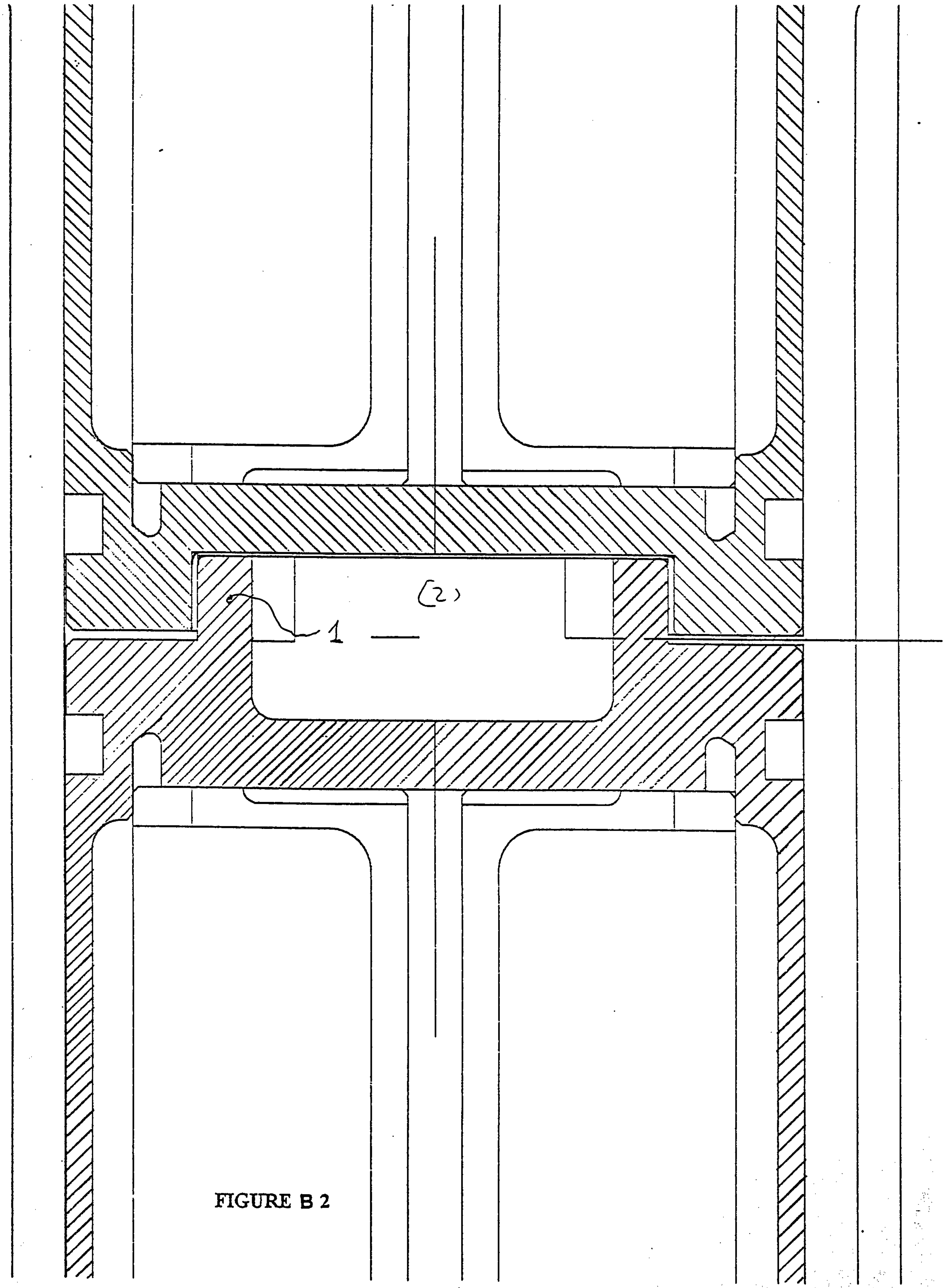


FIGURE B 2

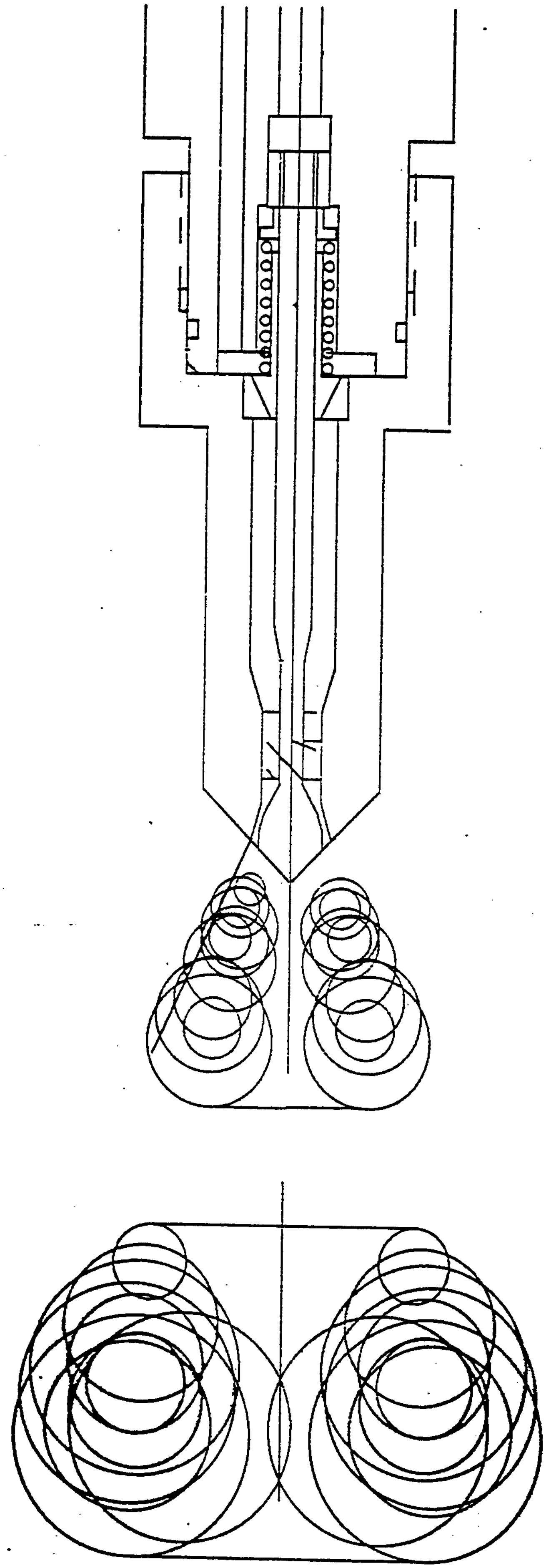
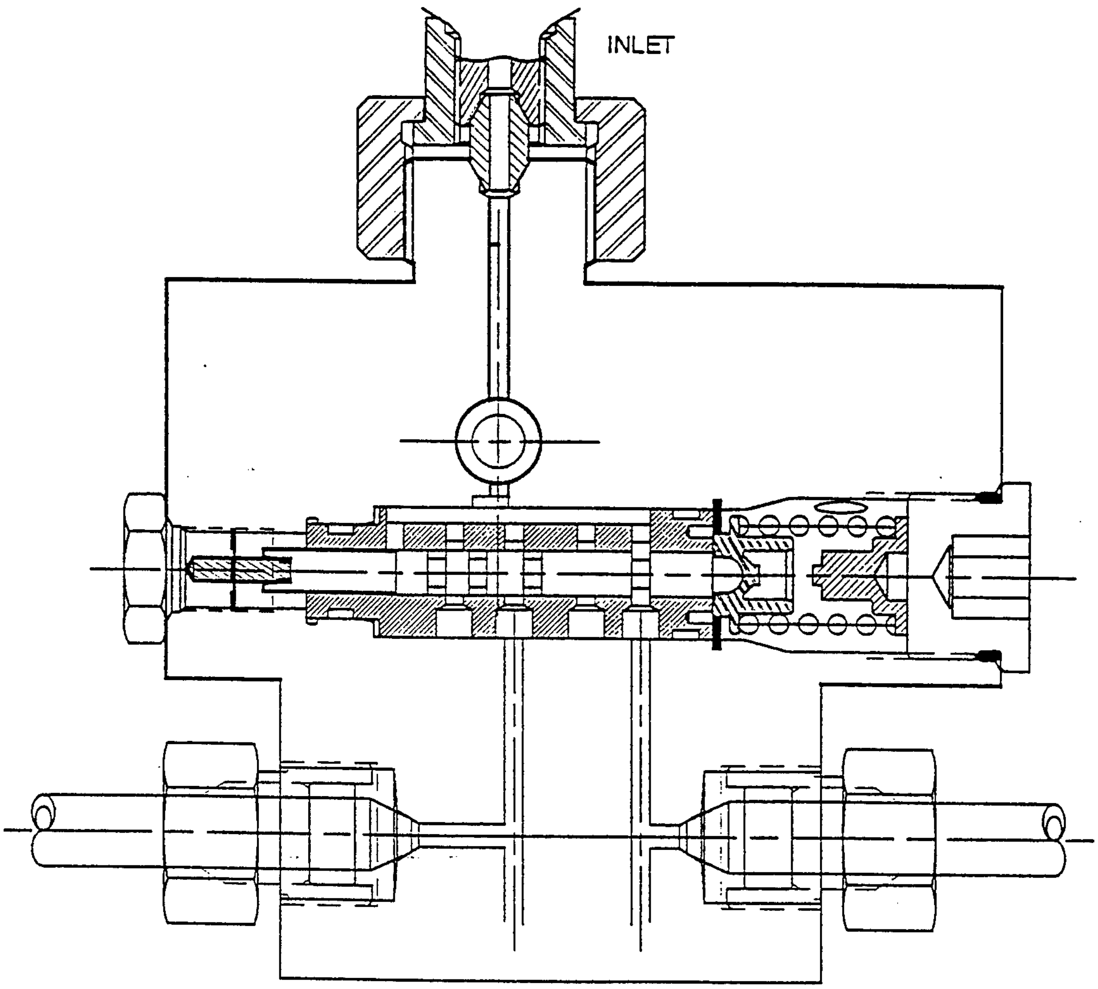
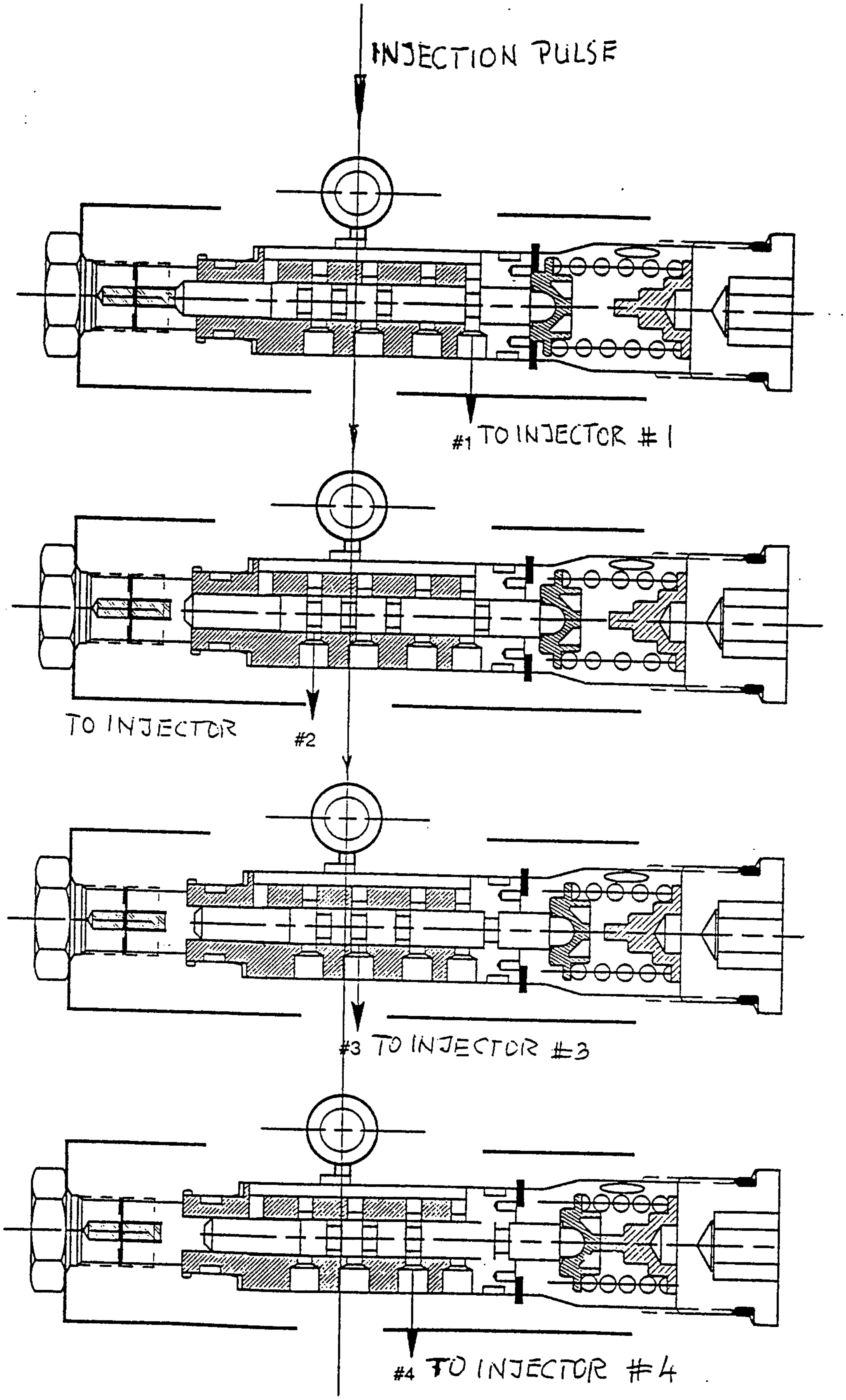


FIGURE 3

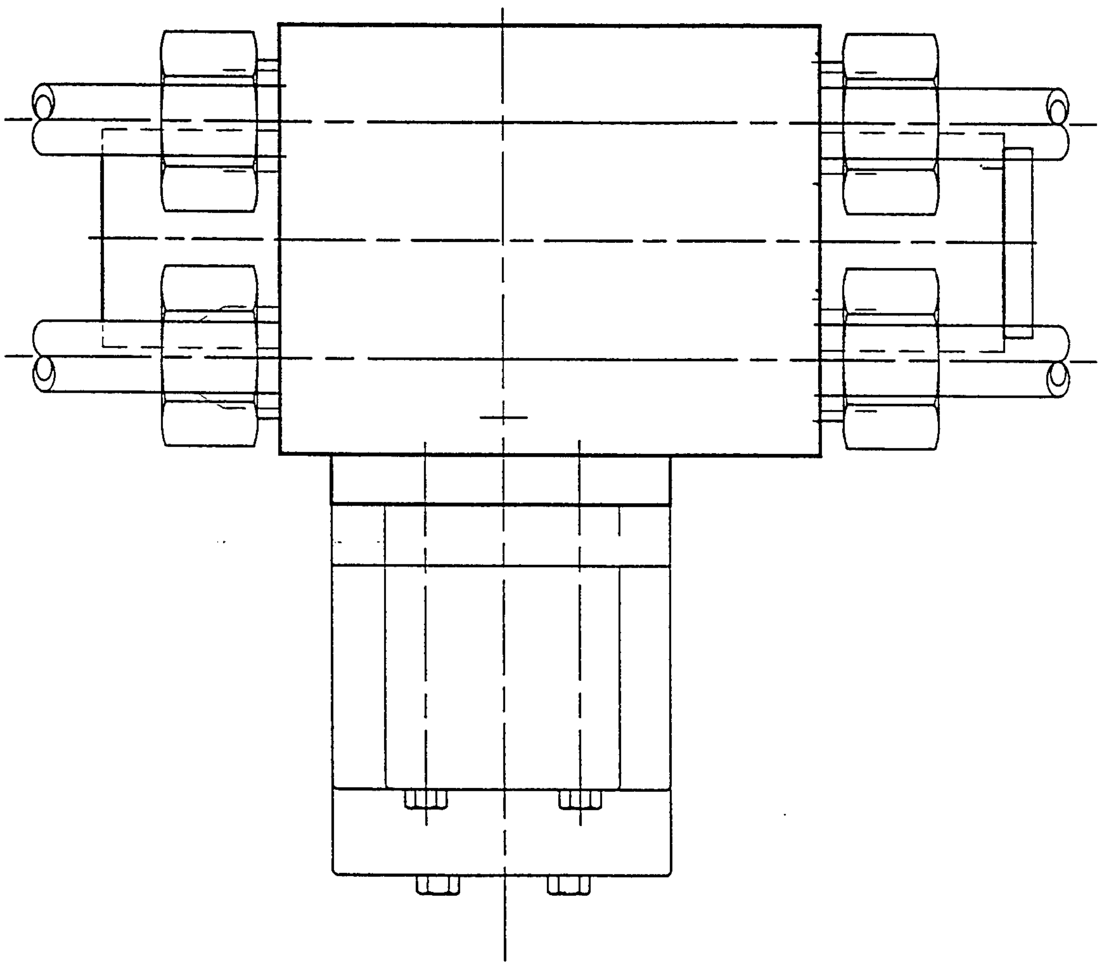


SELF DISTRIBUTION FUEL
DEVICE CROSS SECTION
FIGURE 4

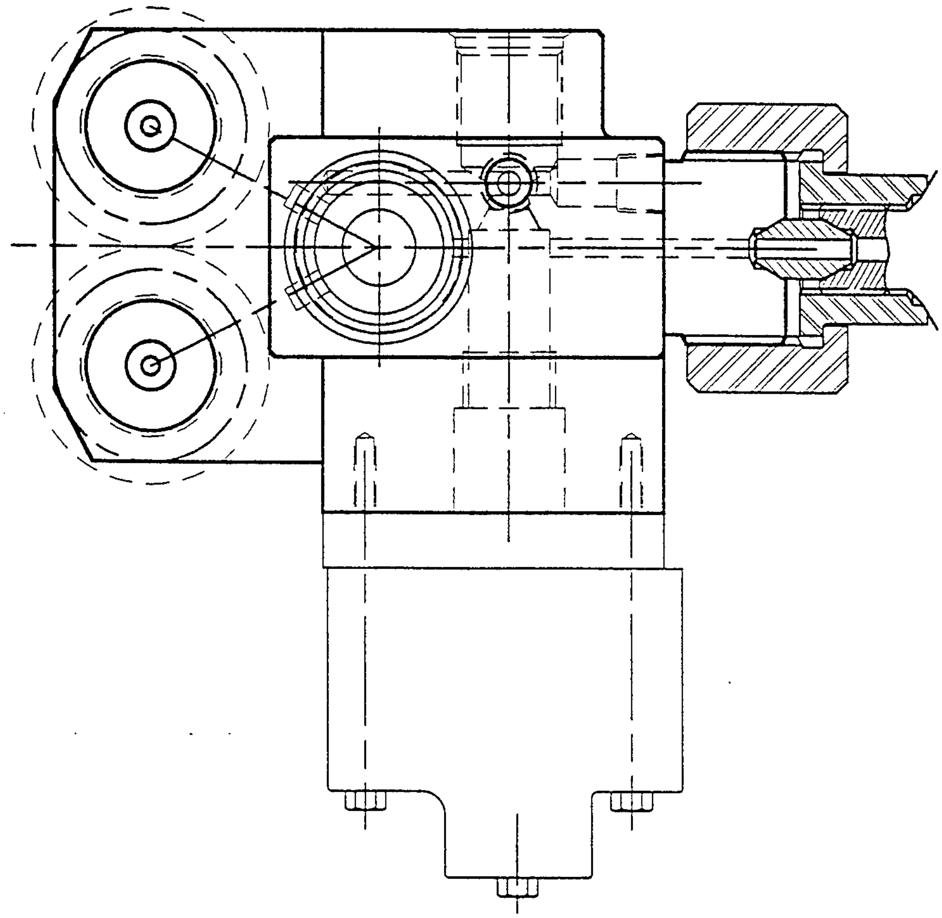


SEQUENCE VALVE MOVEMENT DESIGN #3 9-19-97 RLM

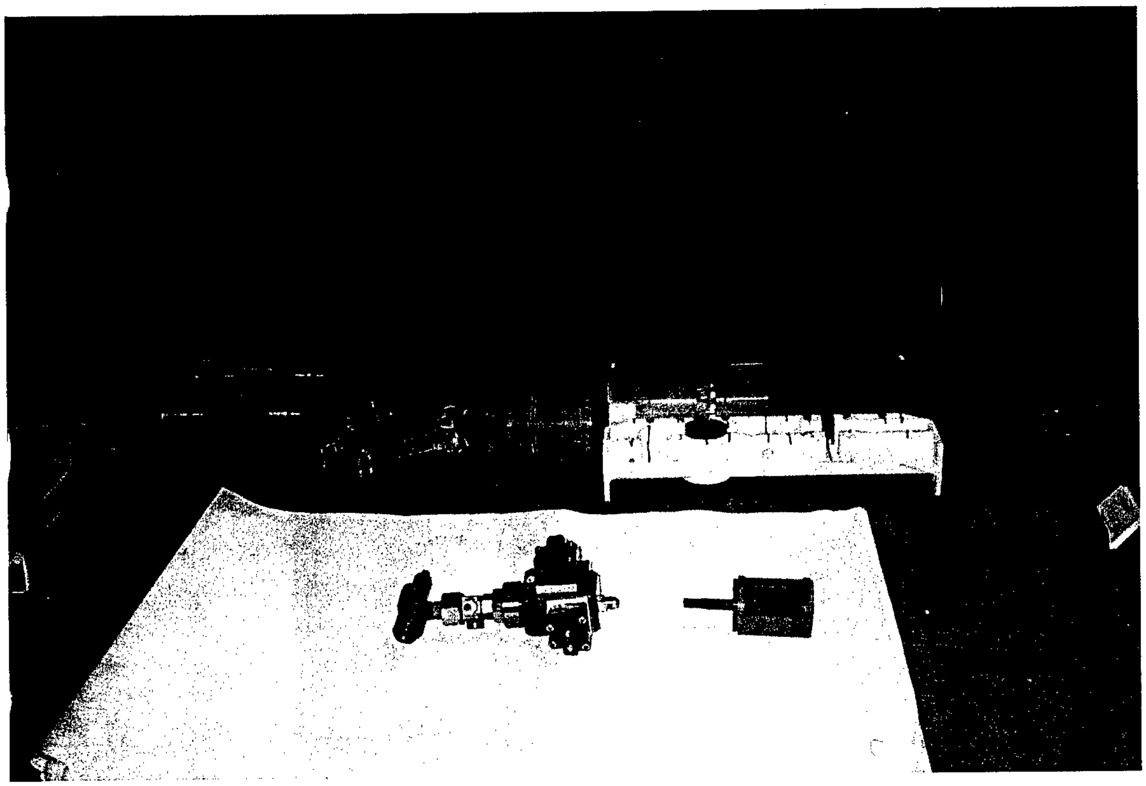
SELF DISTRIBUTION FUEL DEVICE INTERNAL VALVE
FIGURE 4A

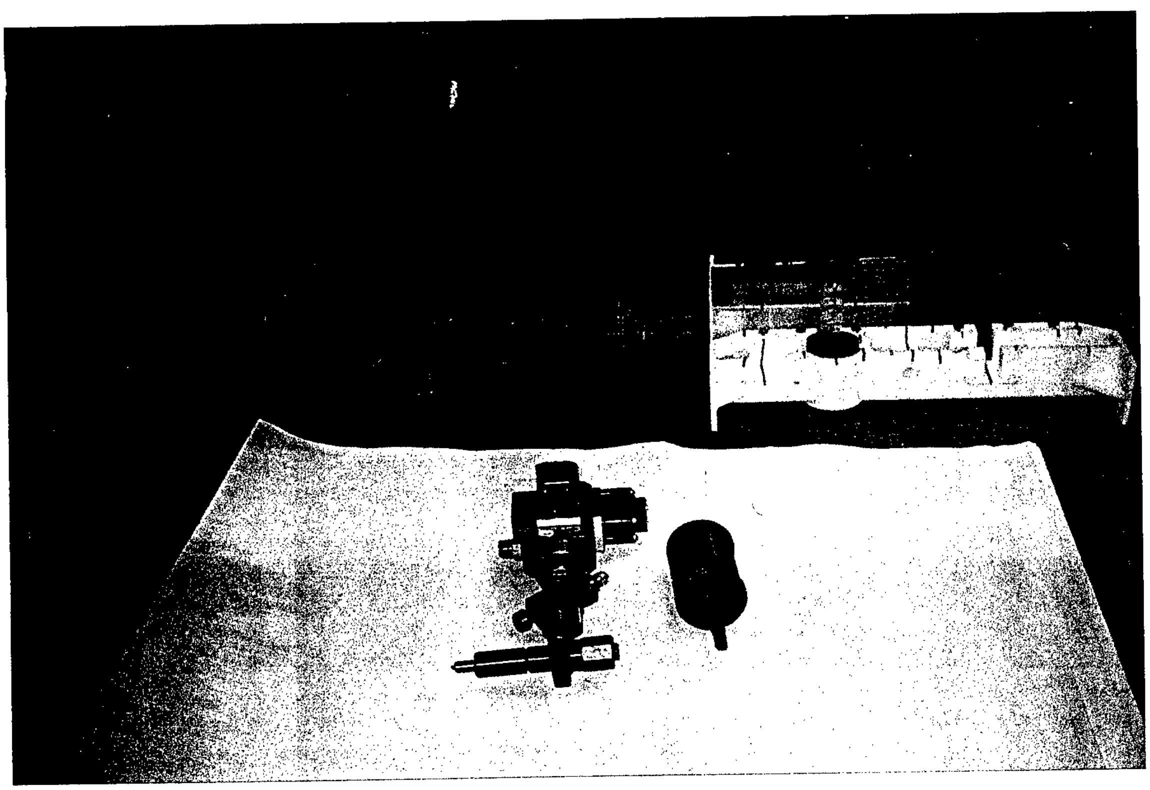


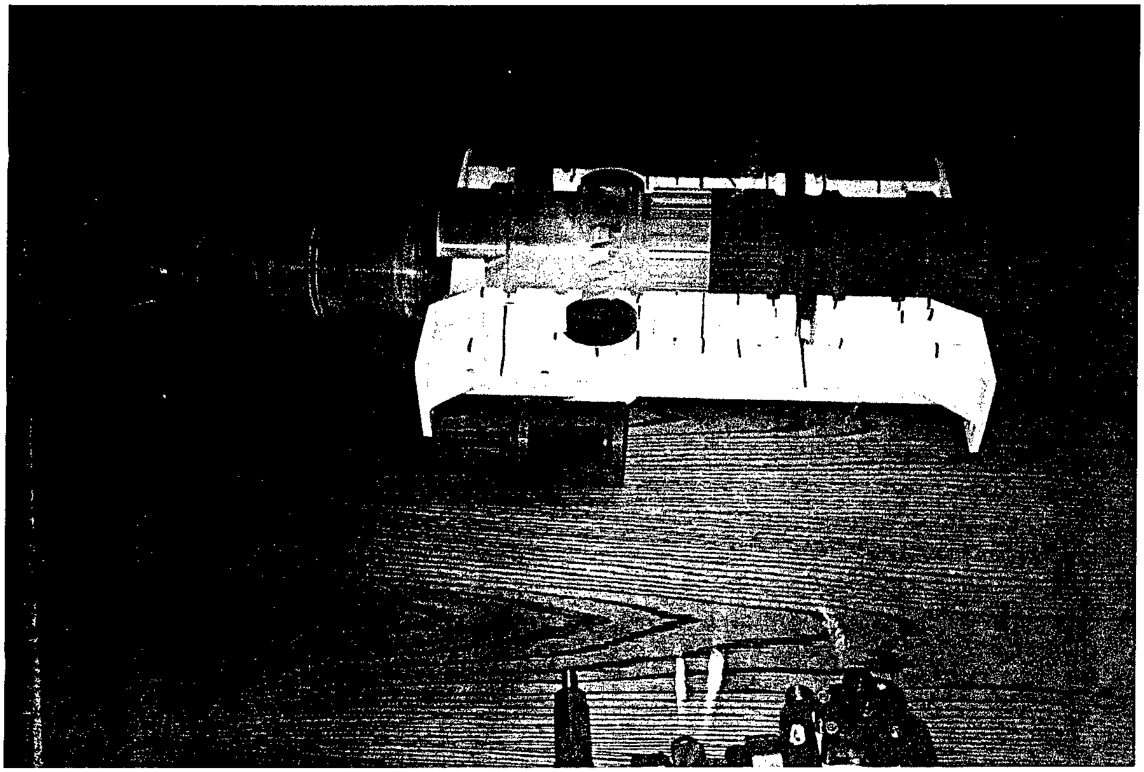
SELF DISTRIBUTION FUEL
DEVICE TOP VIEW
FIGURE 5

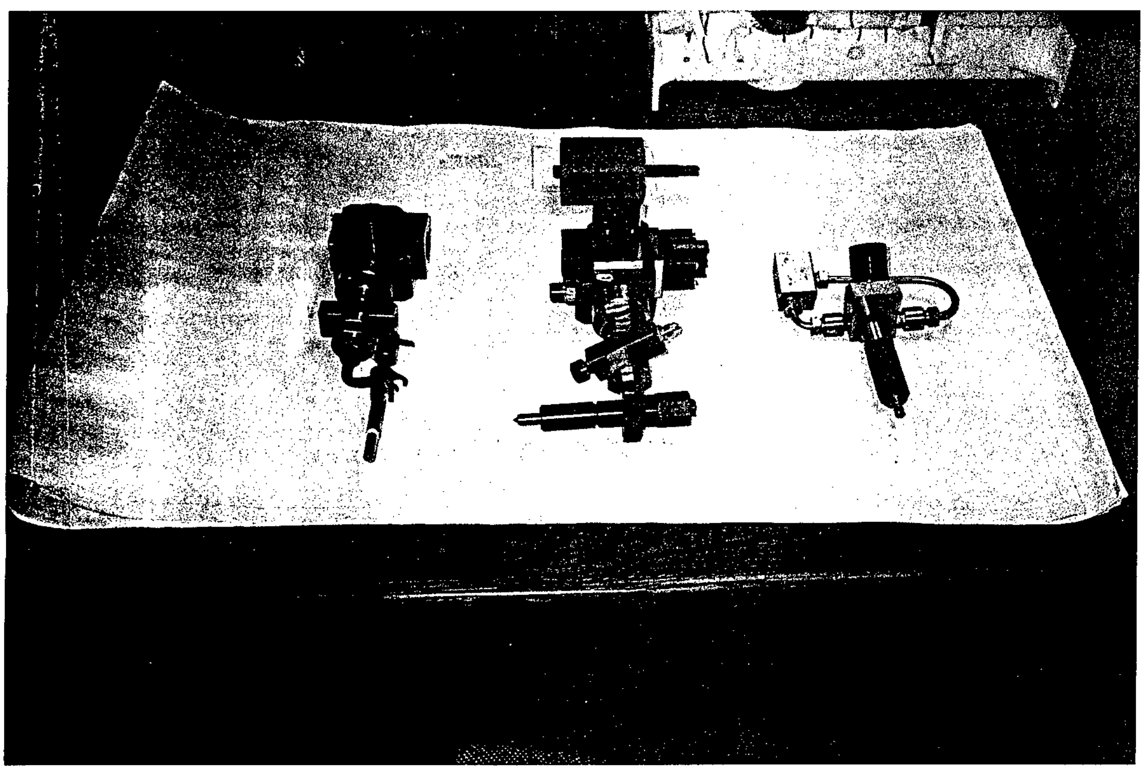


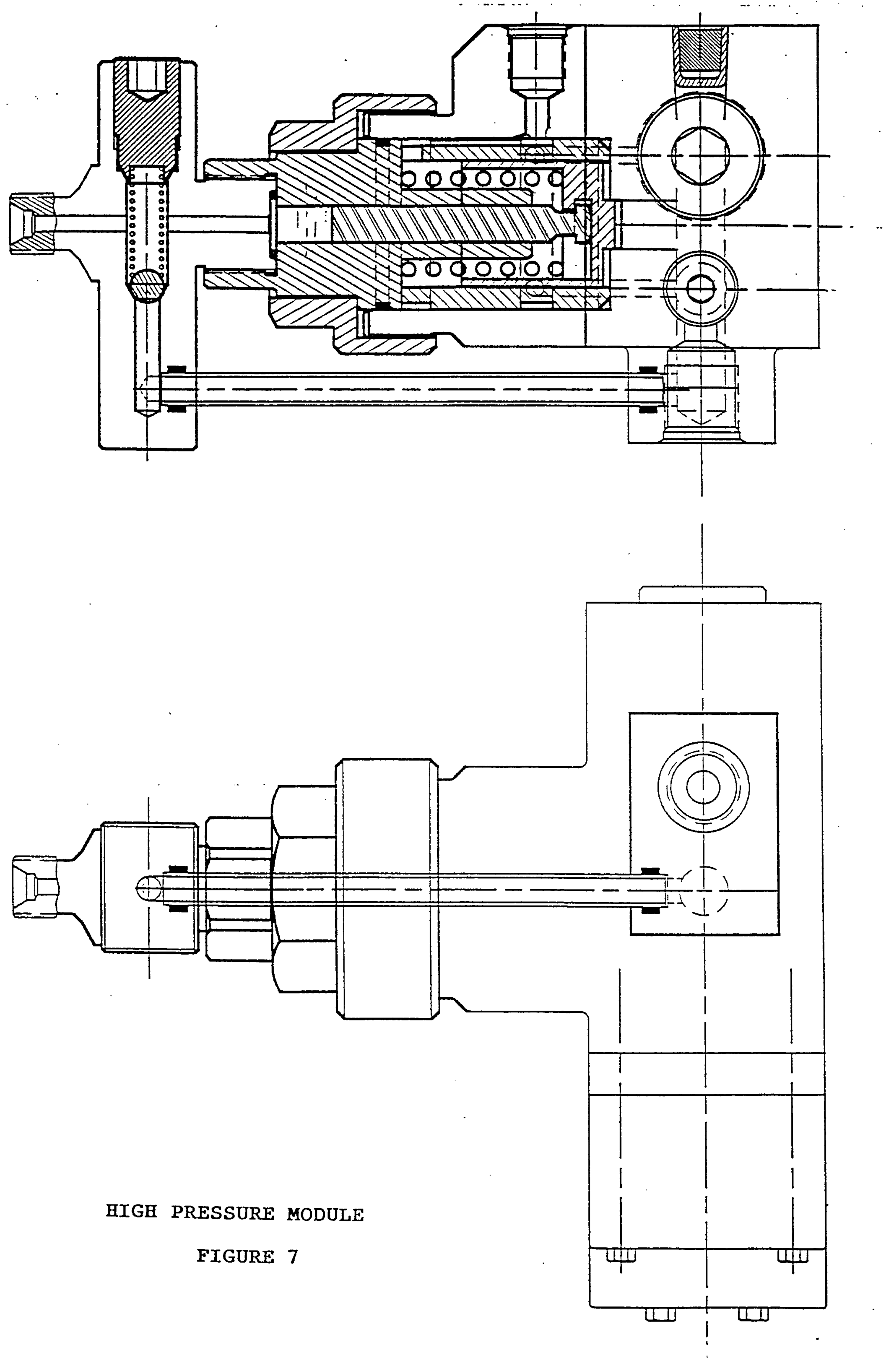
SELF DISTRIBUTION FUEL
DEVICE SIDE VIEW
FIGURE 6











HIGH PRESSURE MODULE

FIGURE 7

TASK 2.2 FUEL INJECTION OPTIONS ASSESSMENT.

PRELIMINARY SELECTION

THE LARGE VARIETE OF INJECTION SYSTEMS AVAILABLE ON THE MARKET HAVE A COMPLETE REPREZENTATION IN THE BOSCH INJECTION SYSTEMS CATALOG AND PRODUCTION AVAILABILITY, WHICH CAN BE A GOOD GUIDE FOR THE ASSESSMENT OF THE STATE OF THE ART INJECTION SYSTEMS , CONSIDERED "CONVENTIONAL TECHNOLOGY "

A DEPARTURE FROM THE "CONVENTIONAL TECHNOLOGY" CAN BE REPREZENTED BY THE "HEUI FUEL SYSTEM" PRODUCED BY CATERPILAR AND NAVISTAR

ALL OTHER INJECTION SYSTEMS ARE VERY FAR FROM ANY CONSIDERATION , REPREZENTING THE"OLD" HISTORY WHICH CAN NOT BE A POTENTIAL COMPONENT OF OUR ADVANCED ENGINE TECHNOLOGY.

STARTING OUR ANALYSIS ON THE "BASIC CRITERIAS", AND USING THE INFORMATIONS PUBLISHED IN THE "DIESEL & GAS TURBINE WORLD WIDE CATALOG "97", AND PUBLICATIONS FROM DIFERENT SOURCES INCLUDING SAE REPORTS, FOR THE FUNDAMENTAL CRITERIA OF THE" HIGHEST INJECTION PRESSURE POSSIBLE " , WE CAN CONCLUDES:

THE MAXIM ABSOLUTE INJECTION PRESSURE OF ALL

EXISTING INJECTION SYSTEMS

IS 2000 BAR = 30, 000 PSI

PROVIDED BY "BOSCH ELECTRONICALLY CONTROLLED UNIT INJECTORS (EUI).

1. THIS UNIT INJECTORS CAN BE USED ONLY IN SPECIAL CONFIGURATION ENGINES PROVIDED WITH A MECHANICAL DRIVING SYSTEM OF CAMSHAFT , PUSHER , ROCKERS , GEARS , BUILDED SPECIFICALLY FOR THIS INJECTION SYSTEM.

2. THE BOSCH INJECTOR CAN WORK ONLY FOR MAXIMUM COMBUSTION PRESSURE FOR THE THERMAL CYCLE WHICH WILL BE NO MORE THAN

150 – 200 BAR = 2200 – 3000 PSI.

ECA THERMOELECTRIC COMPOUND ENGINE IS CAPABLE TO WORK AT 300 – 350 BAR = 4500 – 5000 PSI, COMBUSTION PRESSURE

2. FOR BOTH REASONS THE BOSCH INJECTION SYSTEM IS UNAPPLICABLE TO THE ECA THERMOELECTRIC ENGINE , BECAUSE DOES NOT HAVE ANY MECHANICAL CAMS , PUSHER , ROCKERS , OR ANY MECHANICAL DRIVING SYSTEM, WITH OUT A MAJOR REDESIGN AND REBUILD THE ENTIRE ENGINE CONFIGURATION .

3. IN ADDITION THE SMALLER INJECTION PRESSURE WILL RESTRICT ECA ENGINE TO DEMONSTRATE THE MAXIMUM POTENTIAL OF THE THERMODYNAMIC CYCLE EFFICIENCY AT 300-350 BARR ,COMBUSTION PRESSURE

4 MULTIPLE PILOT AND MAIN INJECTIONS IS NOT AVAILABLE FOR THE BOSCH INJECTION SYSTEM , WHICH WILL BE DIFICULT OR IMPOSSIBLE TO ELIMINATE THE NOX EMISSION , AND TO ACHIEVE THE MULTIPLE FUEL CAPABILITY.

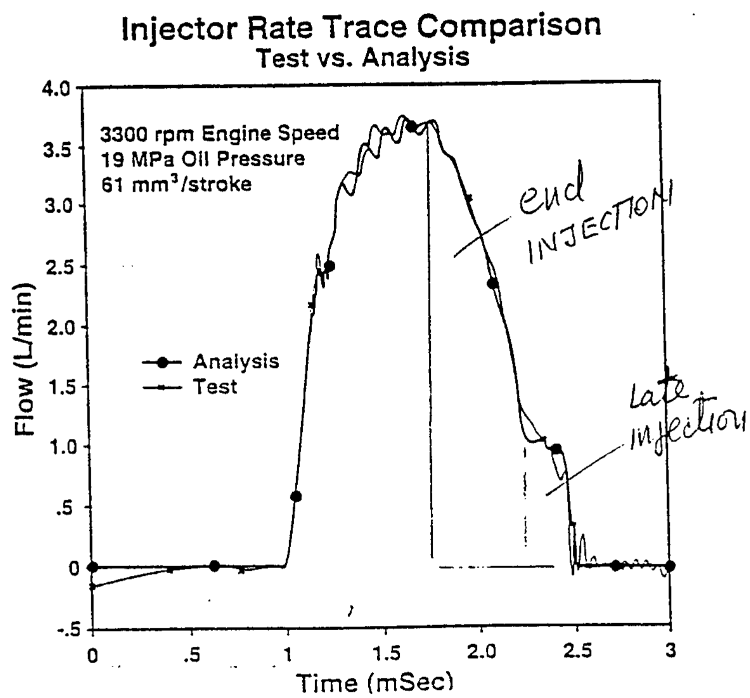


FIGURE 7

HEUI Fuel System

6. THE BOSH UNIT INJECTION SYSTEM , HAVE A LIMITED ROTATION CAPABILITY NOT MORE THAN 2000 RPMS / INJECTIONS PER MINUTE , WHICH IS A RIGID LIMITATION OF THE POWER DENSITY , IN COMPARISSON WITH THE NOMINAL SPEED OF ECA TWO CYCLE ENGINE AT 5500 RPM .

7 THE BOSCH "COMMON RAIL " INJECTION SYSTEM , HAVE MUCH LESS PRESSURE CAPABILITY ONLY 1350 BAR , BUT HIGHER SPEED AT 3000 RPM. THIS INJECTION SYSTEM WILL RESTRICT MORE THE LEVEL OF THE MAXIMUM PRESSURE ACCEPTABLE IN THE COMBUSTION CHAMBER.

CONCLUSION FOR BOSCH INJECTION SYSTEM .

FOR ALL THESE REASONS THE BOSCH INJECTION SYSTEMS ARE NOT APPLICABLE TO THE ECA THERMOELECTRIC ENGINE WITH OUT SEVERE REDUCTIONS OF THE PERFORMANCESS AND UN ACCEPTABLE MORE COMPLEXITITY .

ANALYSIS OF THE HUI CATERPILAR /NAVISTAR
INJECTION SYSTEM

THE HUI CATERPILAR /NAVISTAR INJECTION SYSTEM IS A DEPARTURE FROM THE CONVENTIONAL INJECTION SYSTEMS , AND AN EXTENTION OF THE COMMON RAIL INJECTION SYSTEM CONCEPT.

THE BIGEST LIMITATION OF THE HUI SYSTEM IS IN RELATION WITH THE MAXIMUM INJECTION PRESSURE OF 1500 BAR , LESS THAN THE BOSCH UNIT INJECTION SYSTEM , ANALIZED ABOVE (2000 BAR).

ACTUAL DEVELOPMENT WORK PUBLISHED BY CATERPILAR , IS INDICATING THAT THE MOST SEVERE PRESSURE LIMITATION IS ASSOCIATED WITH THE GEOMETRY OF THE NOZZLE (TIP) HOLES , AND POPET VALVE FUNCTIONALITY.

THE MOST IMPORTANT DEFICIENCY OF THE HUI INJECTION SYSTEM IS THE "INJECTOR RATE TRACE " PUBLISHED IN THE SAE 930271 FIG 7.

THIS RATE IS INDICATING THAT APROX 50% OF THE INJECTION , AT THE END IS A VERY SLOW DECAYING PRESSURE DROP ,INCLUDING WITH A "REZIDUAL" VERY LOW PRESSURE END "STEP " INJECTION (25%).

BECAUSE 50% OF THE INJECTION AT THE END OF COMBUSTION , AT MAXIMUM COMBUSTION PRESSURE IS ASSOCIATED WITH REDUCED INJECTION PRESSURE , THE COMBUSTION AND THE FUEL ATOMIZATION IS BADLLY AFFECTED, AND CORRESPONDENTLY THE EMISSION LEVEL WILL BE HIGHER.

THE MOST IMPORTANT PROBLEM ASSOCIAYED WITH THE COMMON RAIL HEUI INJECTION SYSTEM , FOR MORE THAN ONE INJECTOR OR MORE THAN ONE CYLINDER IS THE "HELMHOLTZ PRESSURE INSTABILITY" PHENOMENON , OCCURS WHEN AN INJECTOR FROM ONE MANIFOLD IS ACTUATED AND EXCITES A" PRESSURE WAVE" THAT TRAVELS TO THE OTHER MANIFOLDS. CREATING BIG INTERFERENCE AND VARIATION OF THE FUEL DELIVERY BETWEEN THE INJECTORS . SINCE THE QUANTITY OF THE FUEL INJECTED ,IS DEPENDENT OF MANIFOLD PRESSURE , THE INSTABILITY AND DIFERENTIATION OF FUEL INJECTIONS , CAN CREATE SEVERE INSTABILITY, AND HIGH DEGREE OF UN PREDICTIBLE COMBUSTION DISTURBANCESS.

THE ECA OPPOSED PISTON ENGINE , IS USING MULTIPLE INJECTORS (1,2,3,4), ON THE SAME TIME INTERVAL SECVENTIALLY OPERATED , FOR EACH

CYCLE , THE POTENTIAL INSTABILITY FOR A COMMON RAIL INJECTION SYSTEM , CAN GENERATE TOTALLY UN CONTROLLED COMBUSTION VARIATIONS .

ALL THESE REASONS CONDUCT TO THE CONCLUSION THAT THE CATERPILAR -NAVISTAR INJECTION SYSTEM IS NOT A VIABLE , AND PROPER SOLUTION, FOR THE ULTRA HIGH PRESSURE COMBUSTION CAPABILITY AND ABILITY SPECIFIC UNIC CARACTERISTIC OF THE ECA THERMOELECTRIC COMPOUD ENEGINE.

FINAL CONCLUSION FOR TECHNOLOGY AND MARKET ANALYSIS.

1 . NONE OF THE EXISTING INJECTION SYSTEMS, AVAILABLE ON THE MARKET ARE ABLE TO PERFORM AT THE MAXIMUM CAPACITY ,FOR MAXIMUM INJECTION PRESSURE , TO SATISFY THE MAXIMUM COMBUSTION PRESSURE OF 300—350 BAR SPECIFIC FOR MAXIMUM UNIC PERFORMANCESS AND CAPABILITY OF THE ECA ULTRA HYGH PRESSURE THERMOELECTRIC COMPOUND ENGINE.

2 . NONE OF THE EXISTING INJECTION SYSTEMS ARE ABLE TO PRODUCE HOMOGENEOUSE LEAN MIXTURE , CORESPONDENTLY CLEAN COMBUSTION.

3 NONE OF THE INJECTION SYSTEMS ARE ABLE TO PERFORM AT HIGHER ROTATIONS (PULSATIONS) THAN 3000 /MINUTE.

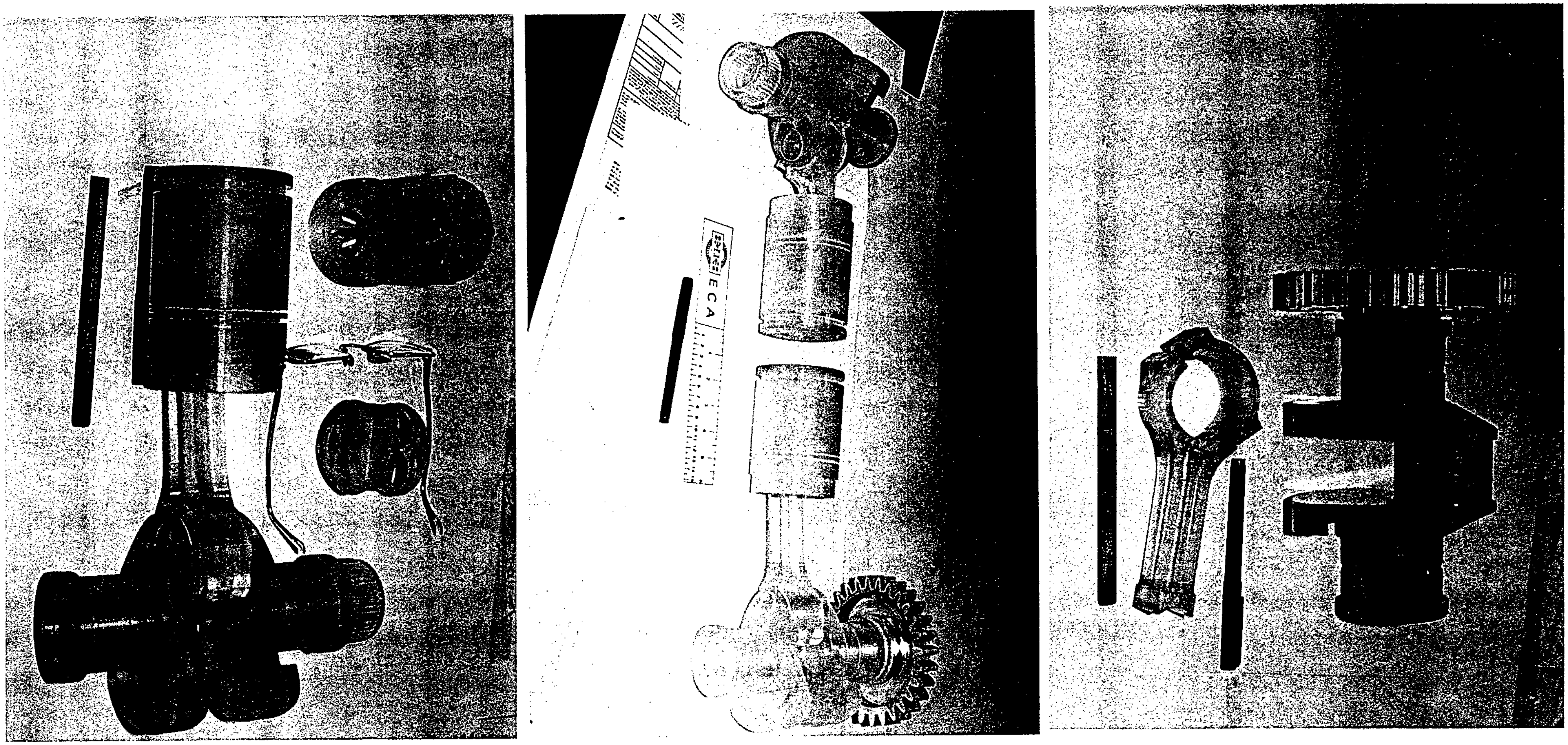


Figure 2

ECA - STEREO LITHOGRAPHY MAIN ENGINE COMPONENTS
REAL SCALE
PRODUCED BY UTAH-UNIVERSITY

Background and Capabilities for University of Utah Involvement

Background

In 1991, we were given the drawings to the 1.5 liter mono-cylinder test engine by our DARPA program manager and asked to first model the engine and then manufacture a 1/3 scale physical model of the engine as test of our ability to model and manufacture a relatively complex assembly. We actually built two physical models, first a plastic model using the stereo lithography process and then the aluminum model. Most of the parts for the aluminum model except for the cylinder block and the cylinder liner were machined directly from solid aluminum stock. The cylinder block and cylinder liner were investment cast from wax models made using the selective laser sintering technique and then finish machined. In addition to the physical models, a complete computer animation of the engine was also produced.

Current Status of the 1.0 Liter Engine

A preliminary computer model of the 1.0 liter engine (87 mm bore and 84 mm stroke) has been completed and physical models of most of the major parts have been fabricated using either the stereo lithography process or the fused deposition modeling process. The same STL files used to produce the rapid prototyping models of the cylinder block, cylinder liner, the rotary valves and the pistons have been provided to FEV Engine Technology for use in computer fluid dynamic analysis. The computer model is completely parametric and is relatively easy to modify. It has already undergone major modifications in the preliminary design phase and has been used as the starting basis for studies of both smaller and larger displacement engines. The engine has also modeled in a manner that would allow building multi-cylinder versions.

The computer model supports both rapid prototyping using the layered technology (STL files) and automatic generation of CNC machining code allowing parts to be made using either or both techniques.

Projected Manufacturing Techniques for the 1.0 Liter Prototype

For the initial prototypes, most of the parts except for the block can be machined directly from solid stock using a combination of CNC machines. This includes the crankshafts, connecting rods, all piston parts, the rotary valves, the gears, and the crankcase halves. The gear blanks will be turned on a CNC turning center and the teeth and splines would be cut using a CNC wire EDM. The cylinder liner either can be machined directly from thick wall alloy mechanical tubing using a combination of CNC turning and 5-Axis machining or it can be investment cast from a wax model generated from one of the common rapid prototyping techniques such as Fused Deposition Modeling (FDM) and then finish machined on a CNC lathe.

The block could also be investment cast either from a wax pattern generated one of the common rapid prototyping techniques or using the Soligen Direct Shell Production Casting (DSPC) technique. All of the commercially available rapid prototyping techniques use the same STL file format so any of the techniques could be used if it were thought to offer an advantage. However, we would probably recommend that the block be fabricated using the Stratiform process developed by Ford Motor Company as part of their 100-Day Engine Project. Using this technique, the block is sliced into relatively thick slices that can be machined from solid stock. The slices are stacked and furnace brazed to crate a solid part that has the same structural characteristics as a casting. This process is generally much faster and more economical than the layered rapid prototyping techniques. As a test or this process, we have machined several slices from the engine. In one test, it took only 50 minutes to machine the slice while the same part took 19 hours to make using the FDM rapid prototyping process.

In production, it would be more economical to finish machine the crankcase halves from sand castings. However, it will be much faster and cheaper to machine the initial prototype crankcase halves from solid stock. The crankcase halves were modeled so that they can be completely machined from solid stock with no weight penalty.

Most of the core parts including the crankshafts, the connecting rods, the piston parts, the gears, and the rotary valve parts would probably be CNC machined from solid stock even in moderate production volume. CNC machining the prototype parts provides a direct link to building the engine in production volume once development of the engine has been completed.

Software

The software used for the modeling and manufacturing was developed at the University of Utah as part of what is referred to as the Alpha_1 project. This project was started around 1982 by Richard Riesenfeld and Elaine Cohen to develop computer aided geometric design software based on the use of non-uniform rational B-splines (NURBS). It has been funded primarily by DARPA and NSF and we currently have limited funding from both agencies. There are several different parts of the Alpha_1 project including work on basic computer graphics, animation, scientific visualization, and computer aided engineering, process planning, and manufacturing. While there are a number of different aspects to the overall project, all of it runs together in a well integrated fashion. The software has continuously been updated so that it uses the latest languages and user interface technology.

One of the major advantages of our software over that of the current commercial systems is the integration between modeling and manufacturing. The modeling system is based on the concept of parametric manufacturing features. While, we use a feature based modeler, we can also treat sculptured surfaces or intersecting sets of sculptured surfaces and/or non-sculptured surfaces as features. The state of our process planning and manufacturing software is such that we can automatically or semi-automatically generate CNC code with automatic tool selection and speed and feed calculation for parts with a wide range of complexity. For machined parts, we can generally make it advantageous to use CNC machine tools with lot sizes as small as one. For parts that require casting, we can create patterns for sand casting or investment casting. We can also generate the necessary code to drive other rapid prototyping machines including selective laser sintering and laminate object manufacturing.

The commercial rights to the software have been given to the University of Utah which has in turn granted a spin-off company, Engineering Geometry Systems or EGS, the right to market any commercial developments of the software. The University of Utah retains an interest in Engineering Geometry Systems. Currently, EGS in conjunction with Bridgeport Machines is marketing a commercial software package, EZFeatureMill that uses the software algorithms developed by the Alpha_1 project.

Manufacturing Facilities at the University of Utah

To test the developments in computer aided process planning and manufacturing software, we have what we refer to as the Advanced Manufacturing Laboratory (AML) at the University of Utah. The AML contains state-of-the-art industrial production quality equipment including:

- Cincinnati Milacron T-500 Horizontal 5-Axis Machining Center with an automatic pallet changer.
- Cincinnati Milacron 1210U Turning Center with a C-Axis spindle and powered rotary tools.
- Monarch Cortland VMC45 Vertical Machining Center with a tilt rotary table for 5-Axis machining.
- Bridgeport Machines TorqueCut 22 Vertical Machining Center with a rotary table.
- Charmilles Roboform 40 4-Axis CNC Sinking EDM.
- Charmilles Robofil 300 5-Axis CNC Wire EDM.
- Fanamation 404020 Direct Computer Controlled Coordinate Measuring Machine.
- Stratasys FDM-1650 Fused Deposition Modeling Rapid Prototyping Machine.

The AML is set up as a University recharge center so that we may work on outside projects and charge an hourly rate for use of the facilities.

Time and Cost Estimate for 1.0 Liter Prototype Engine

The following estimates of time and cost to build 3 or 4 copies of a prototype 1.0 liter Engine are based on a number of assumptions. The work would include the final design and construction of the parts required to assemble the core of the reciprocating part of the 1.0 liter compound turbo-diesel based on using certain parts from the 6-cylinder 3.0 liter Mercedes Benz Diesel engine with a 87 mm bore and 84 mm stroke. The parts that would be designed and manufactured include (for each engine):

- 2 Outer Crankcases
- 2 Inner Crankcases,
- 1 Block
- 1 Cylinder Sleeve
- 2 Rotary Valves
- 2 Rotary Valve Sleeves
- 2 Rotary Valve Servo Drives
- 2 Piston Assemblies including the Piston Crown, Outer Sleeve, Piston Inner Support, and Piston Bridge
- 4 Connecting Rod Assemblies including the Connecting Rod, Connecting Rod Cap, and Wrist Pin.
- 4 Crank Shafts
- 4 Crank Shaft Timing Gears
- 2 Idle Timing Gears
- 1 Center Timing Gear

The work would also include designing, procuring, modifying, and/or manufacturing the necessary bolts, bearings, plugs, seals, etc. for the core engine.

It is assumed that either stock or slightly modified Mercedes Benz or equivalent automotive parts will be used for piston rings, main crank bearings, and crank pin bearings.

The work does not include any design or manufacturing effort related to the auxiliary components including coolant circulation pumps, oil scavenge or pressure pumps, fuel injection system, or starting system. Also, the work does not include any design or manufacturing effort related to the compressor or turbine components.

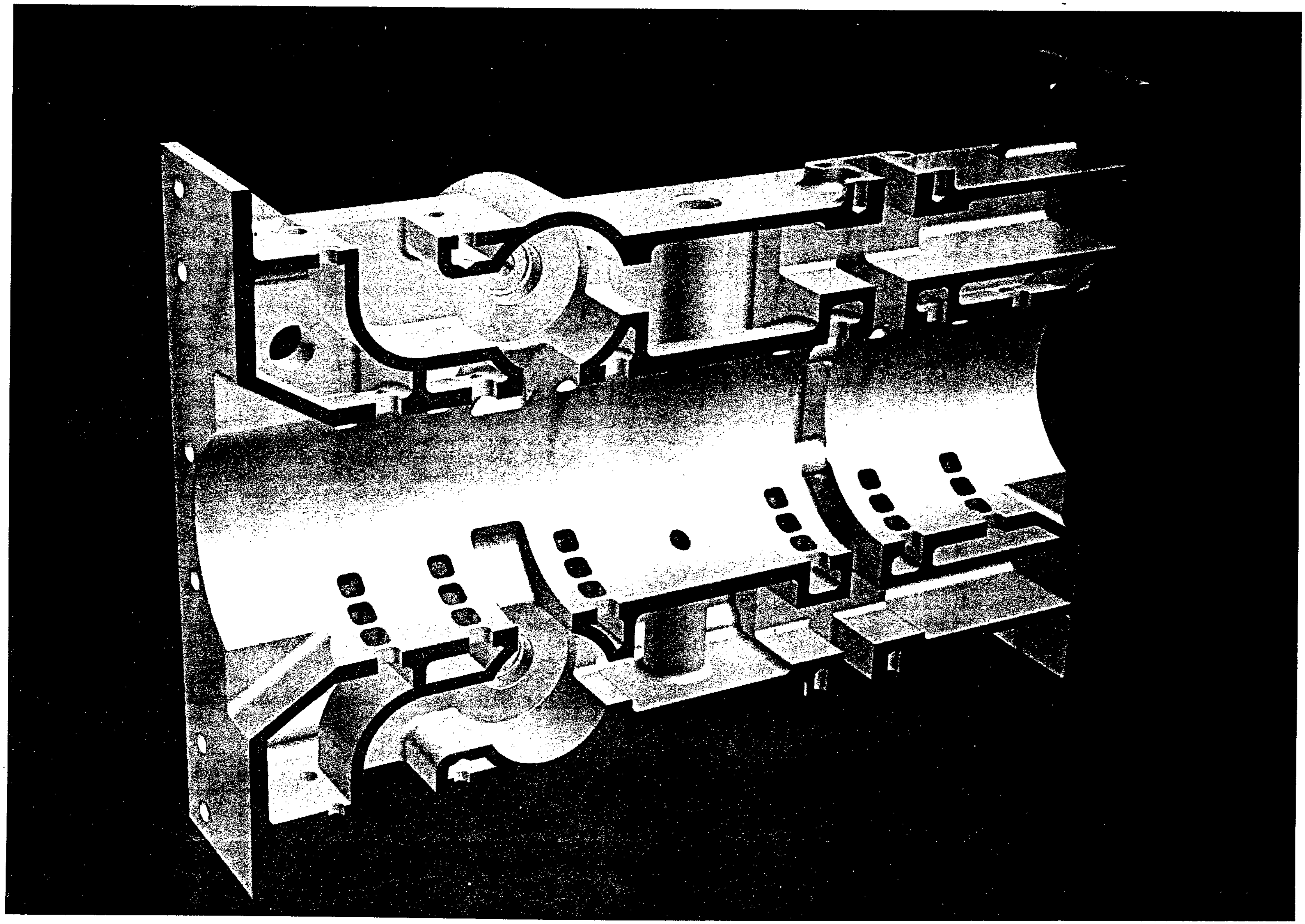
It is assumed that crankshafts, crankcases, connecting rod parts, piston parts, gears, and rotary valve parts will be machined from billet or solid stock. The cylinder liner will either be machined from thick wall alloy mechanical tubing using a combination of CNC turning and 5-Axis machining or it will be investment cast from a wax model generated from one of the common rapid prototyping techniques such as Fused Deposition Modeling (FDM) and then finish machined on a CNC lathe. The prototype block will be fabricated using the Stratiform process developed by Ford Motor Company. Using this technique, the block is sliced into relatively thick slices that can be machined from solid stock. The slices are stacked and furnace brazed to create a solid part that has the same structural characteristics as a casting.

Construction of the prototype engine will not require the design or fabrication of any casting patterns.

Given the above assumptions, I estimate that the core engine components for 3 or 4 prototype engines could be designed and manufactured and assembled in 6 to 8 months for $475,000.

STEREO LITHOGRAPHY

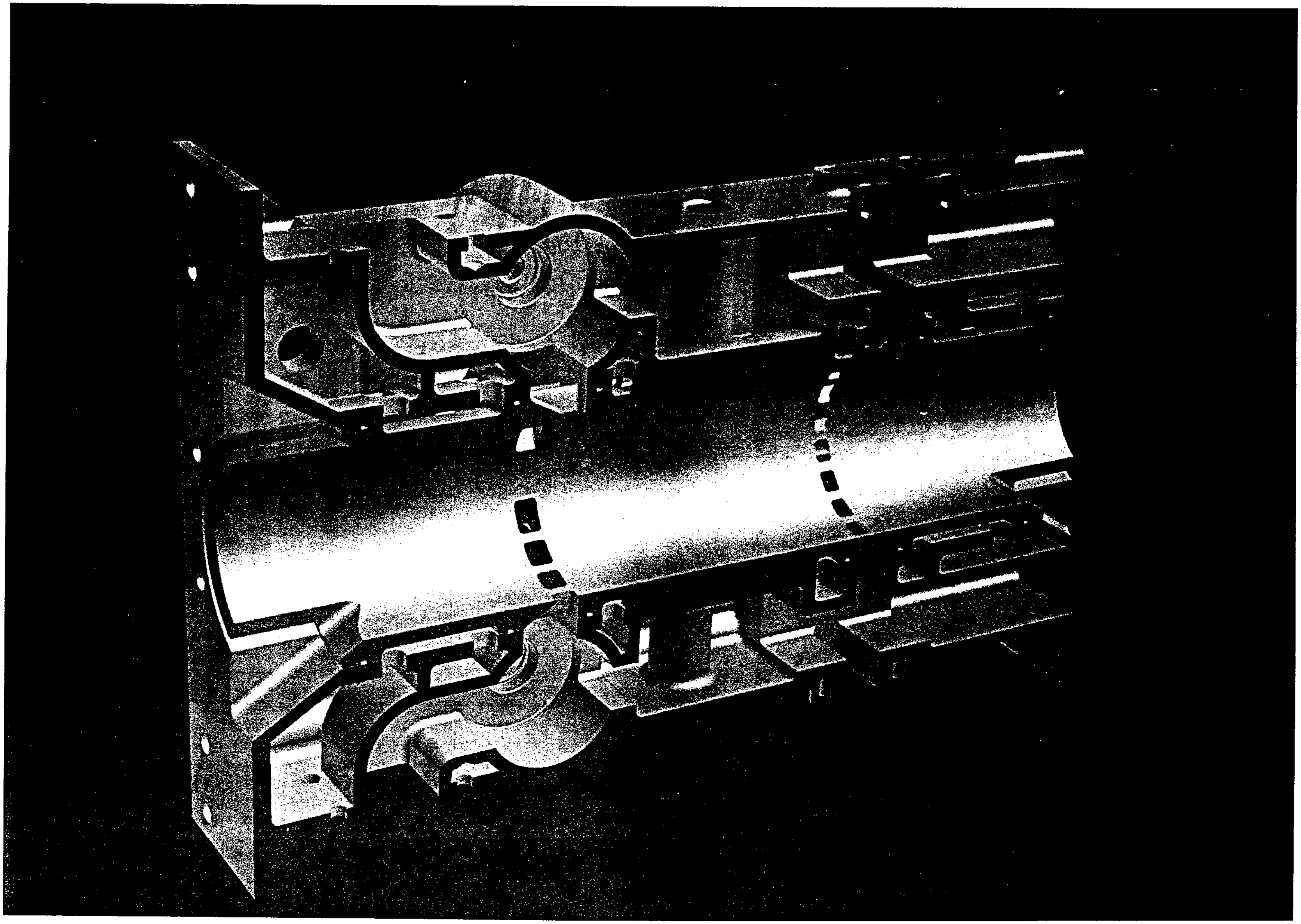
SOLID MODELS



University of Utah
Computer Science

LONGITUDINAL SECTION
MODEL
FOR CYLINDER BLOCK AND
CYLINDER BLOCK

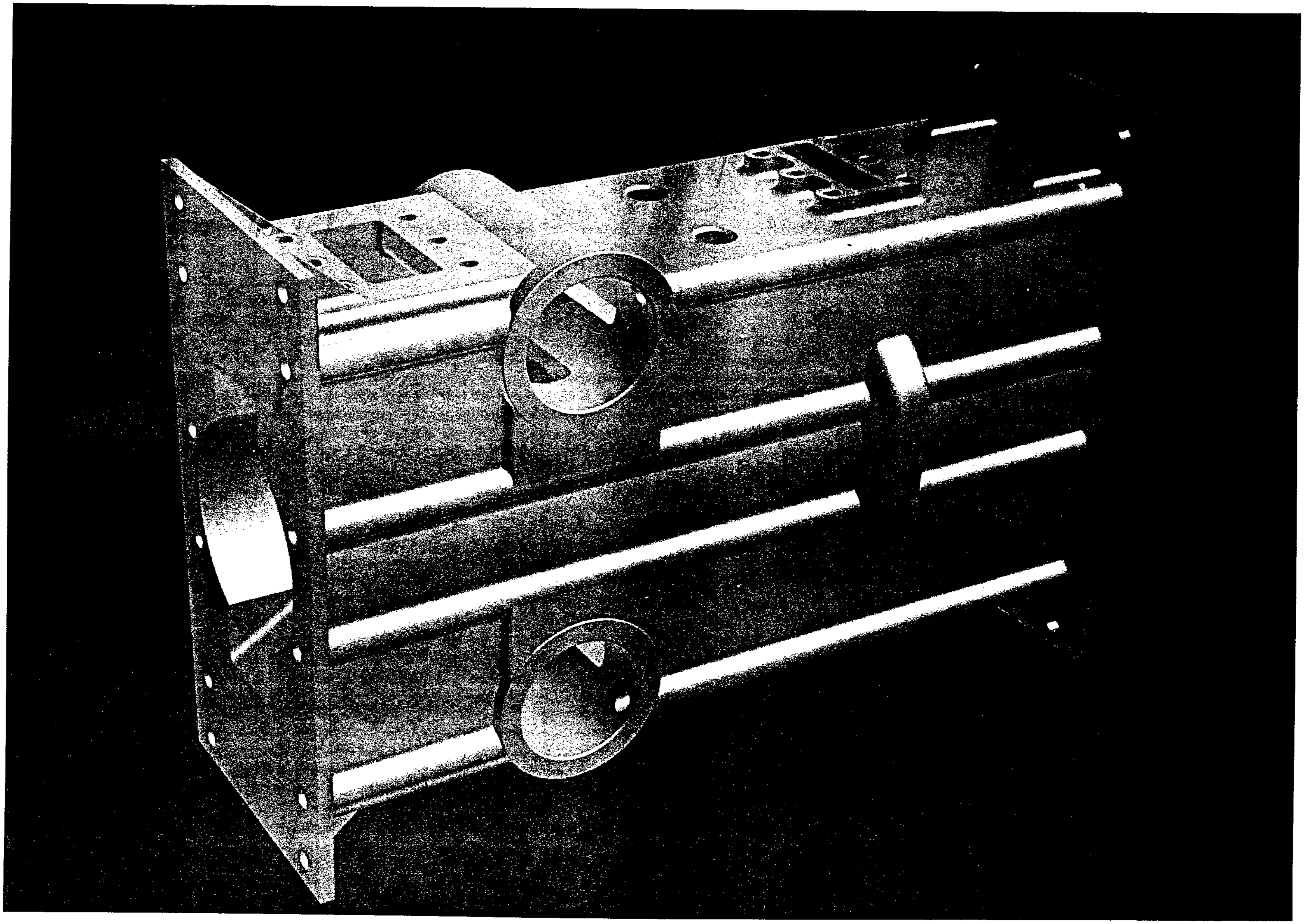
CS 703



University of Utah
Computer Science

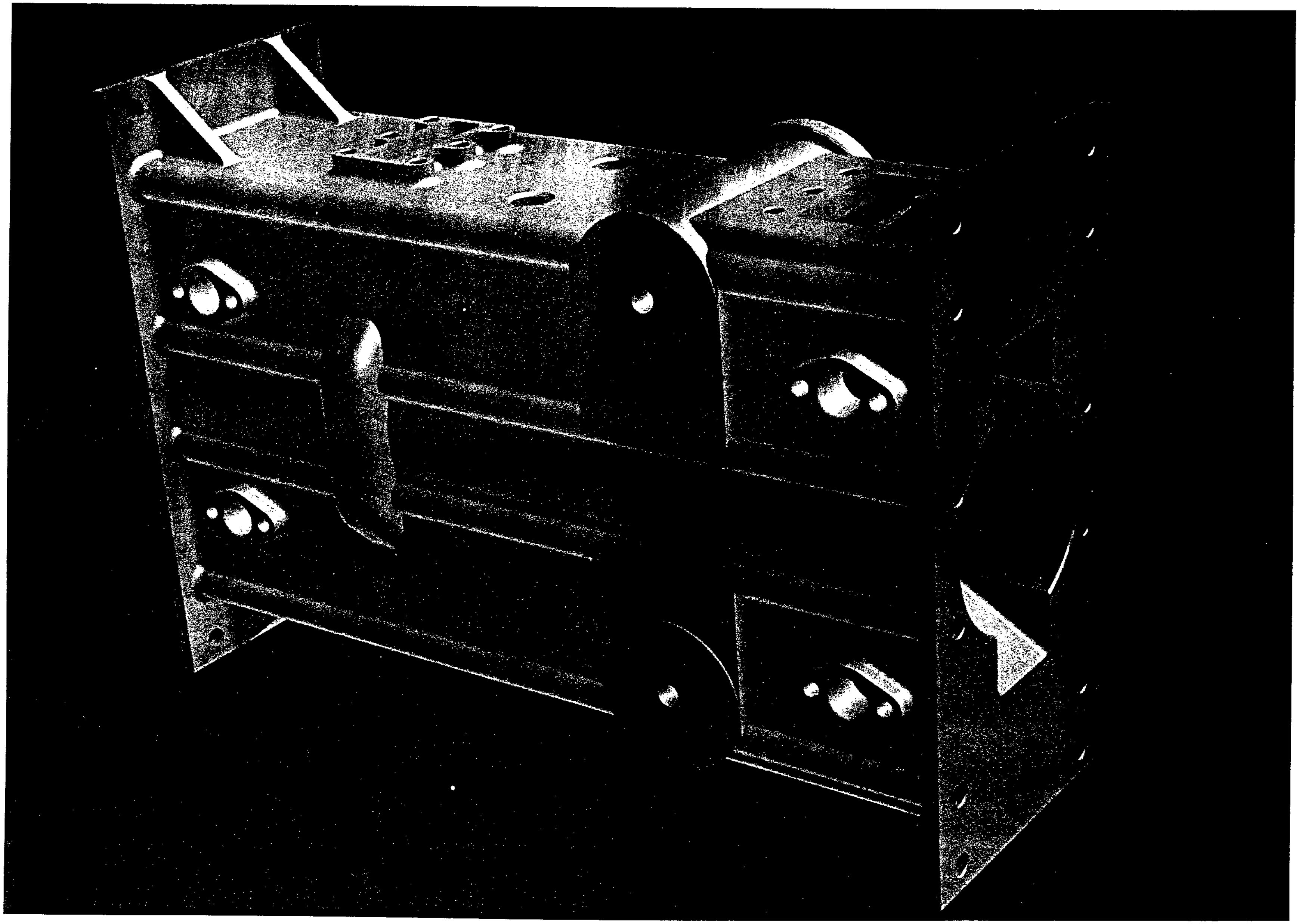
LONGITUDINAL SECTION
MODEL
FOR CYLINDER BLOCK

CS 704



University of Utah
Computer Science

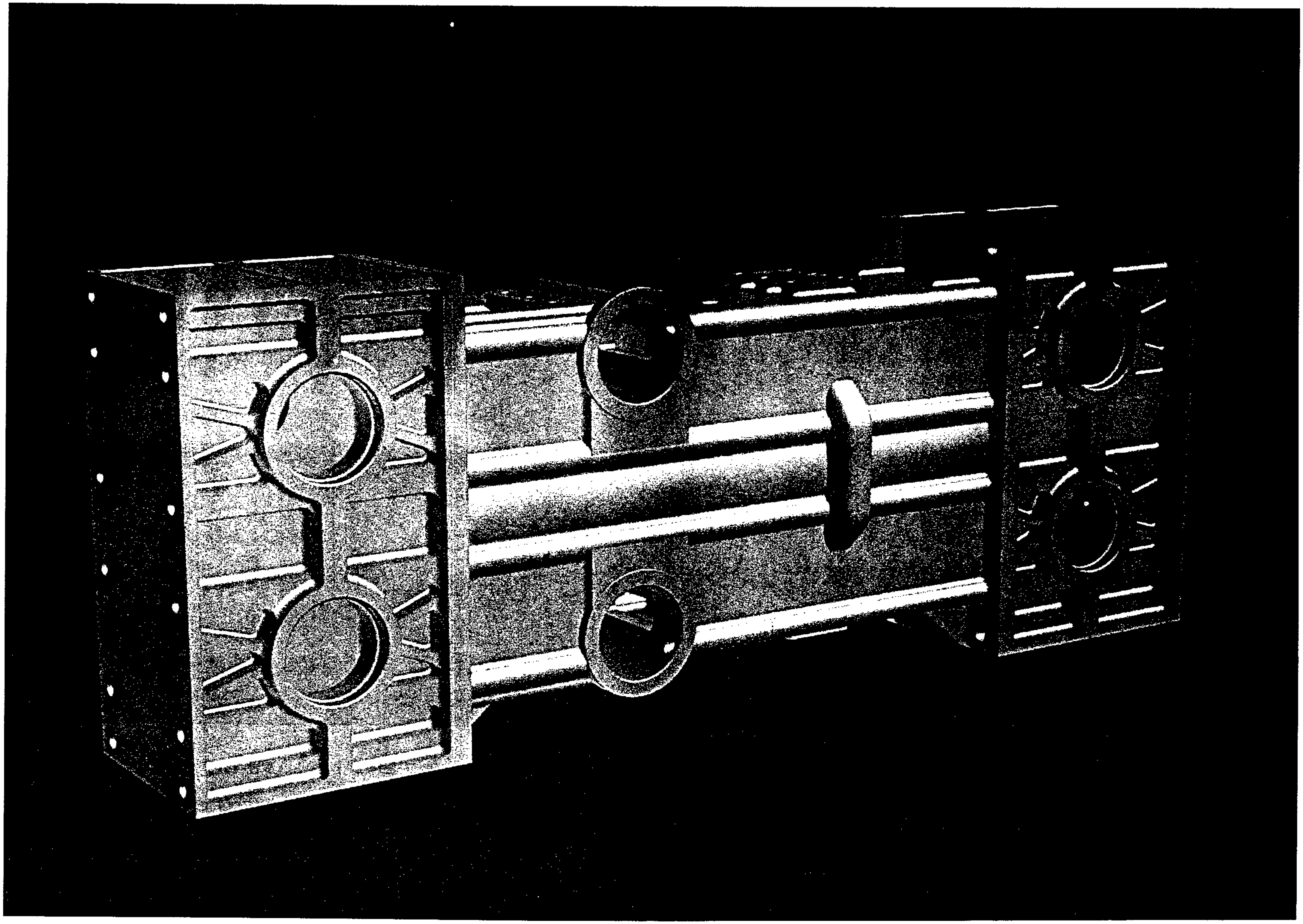
FRONT VIEW OF THE CYLINDER BLOCK



University of Utah
Computer Science

REAR VIEW OF THE CYLINDER BLOCK

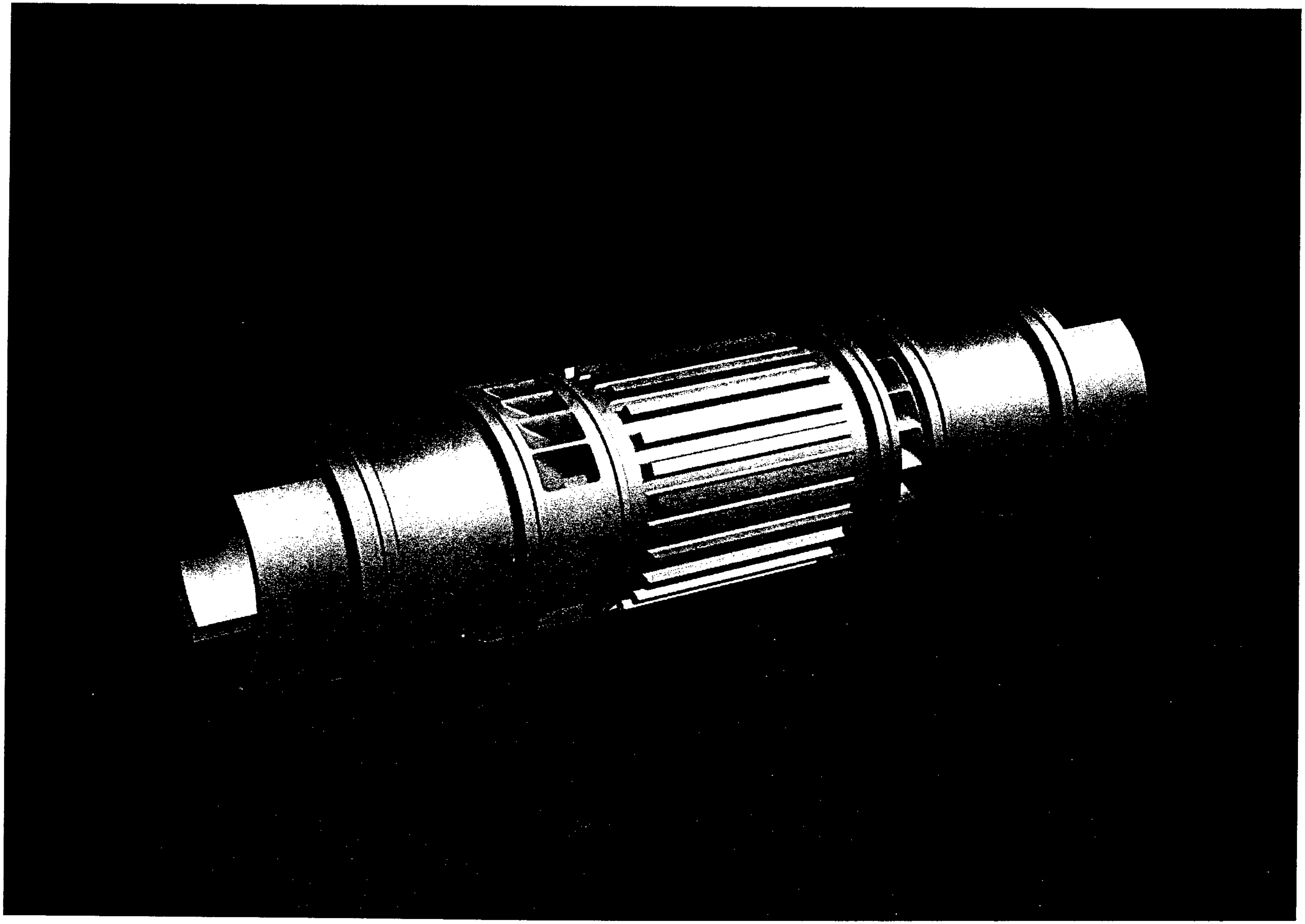
CS 706



University of Utah
Computer Science

COMPLETE ASSEMBLED ENGINE
BLOCK AND CRANKCASE

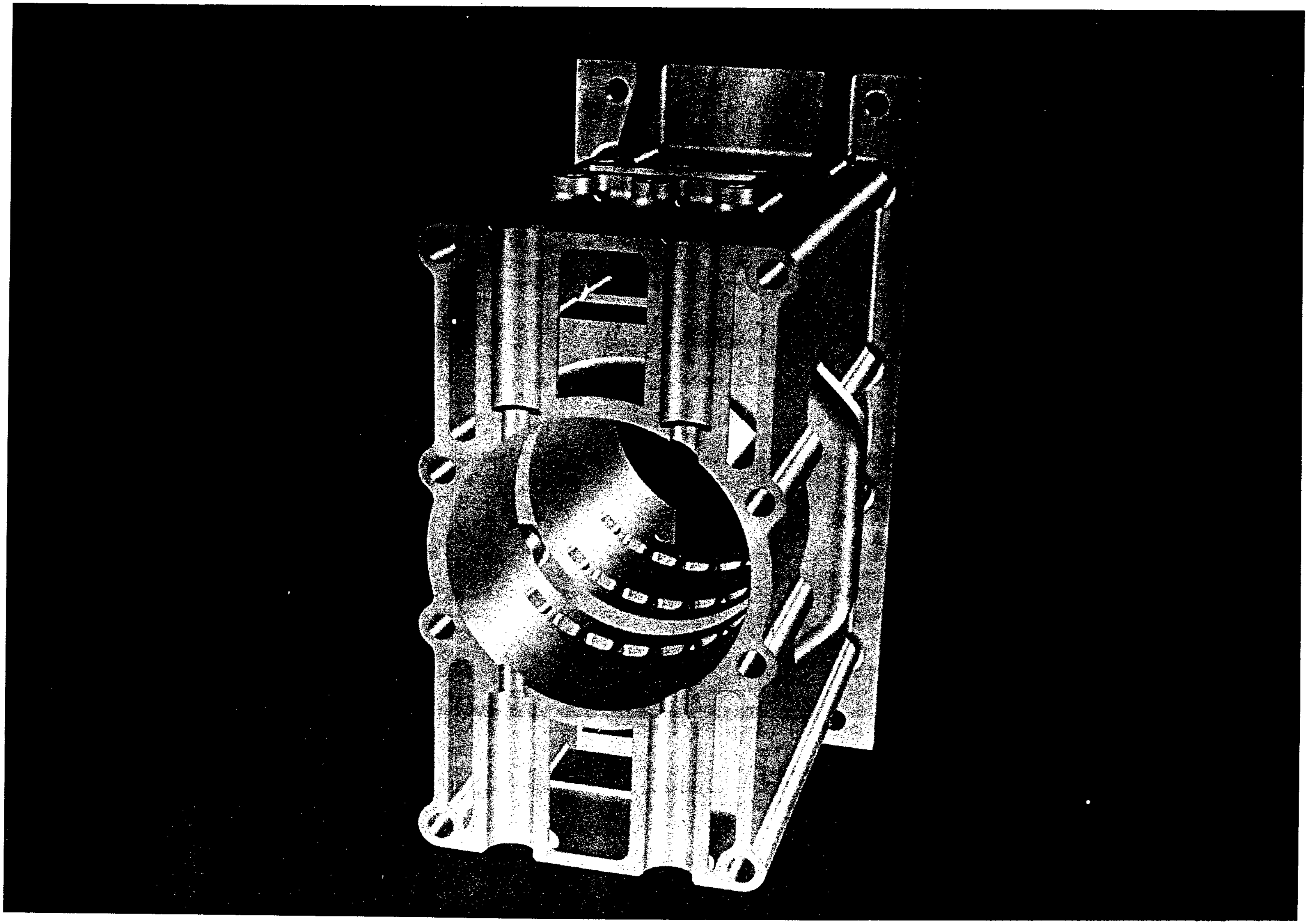
CS 707



University of Utah
Computer Science

CYLINDER LINER FOR OPPOSED
PISTON ENGINE

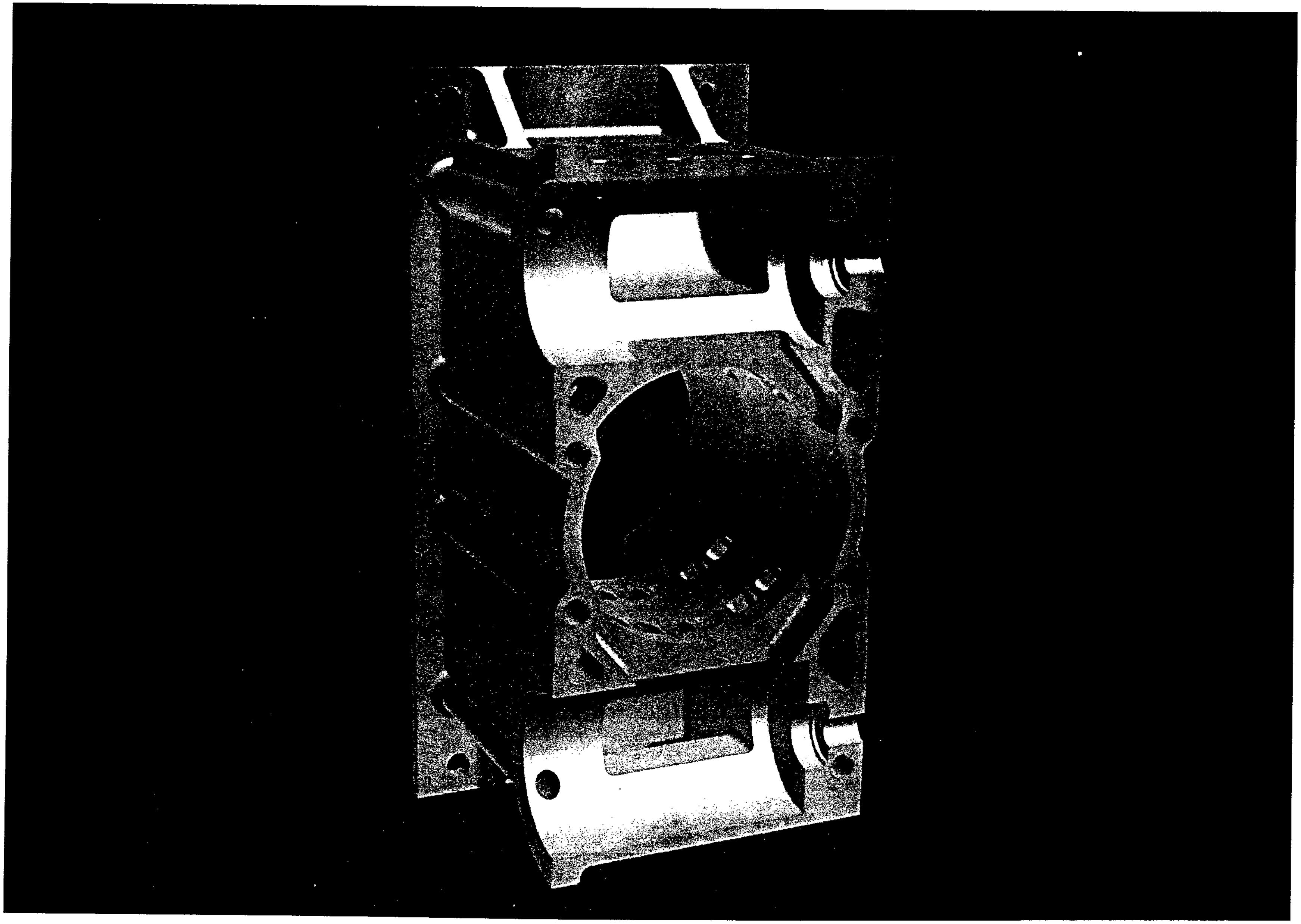
CS 708



University of Utah
Computer Science

CS 709

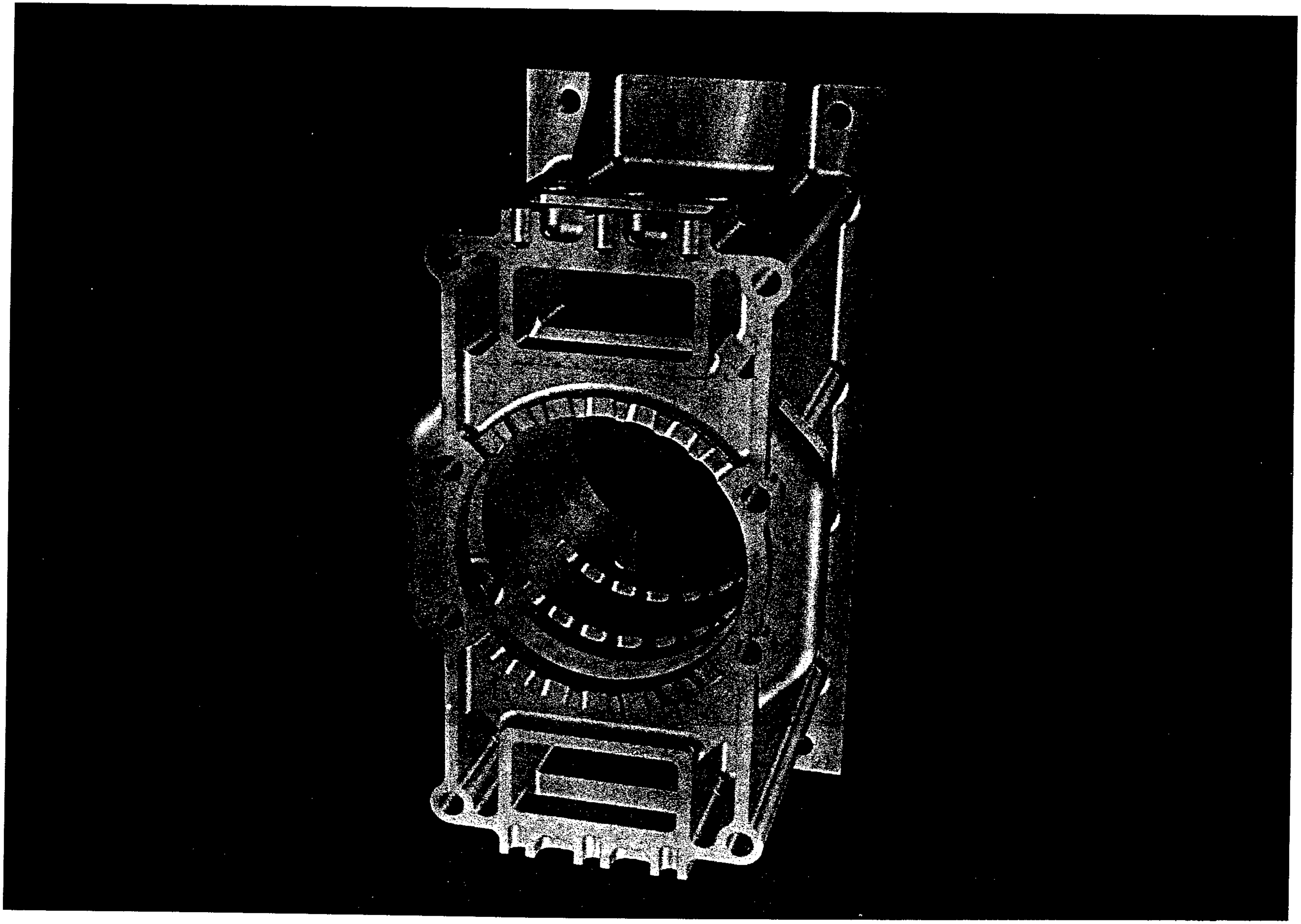
CENTRAL INJECTION SECTION
OF THE CYLINDER BLOCK



University of Utah
Computer Science

TOTAL INTAKE TOTAL EXHAUST
CYLINDER BLOCK

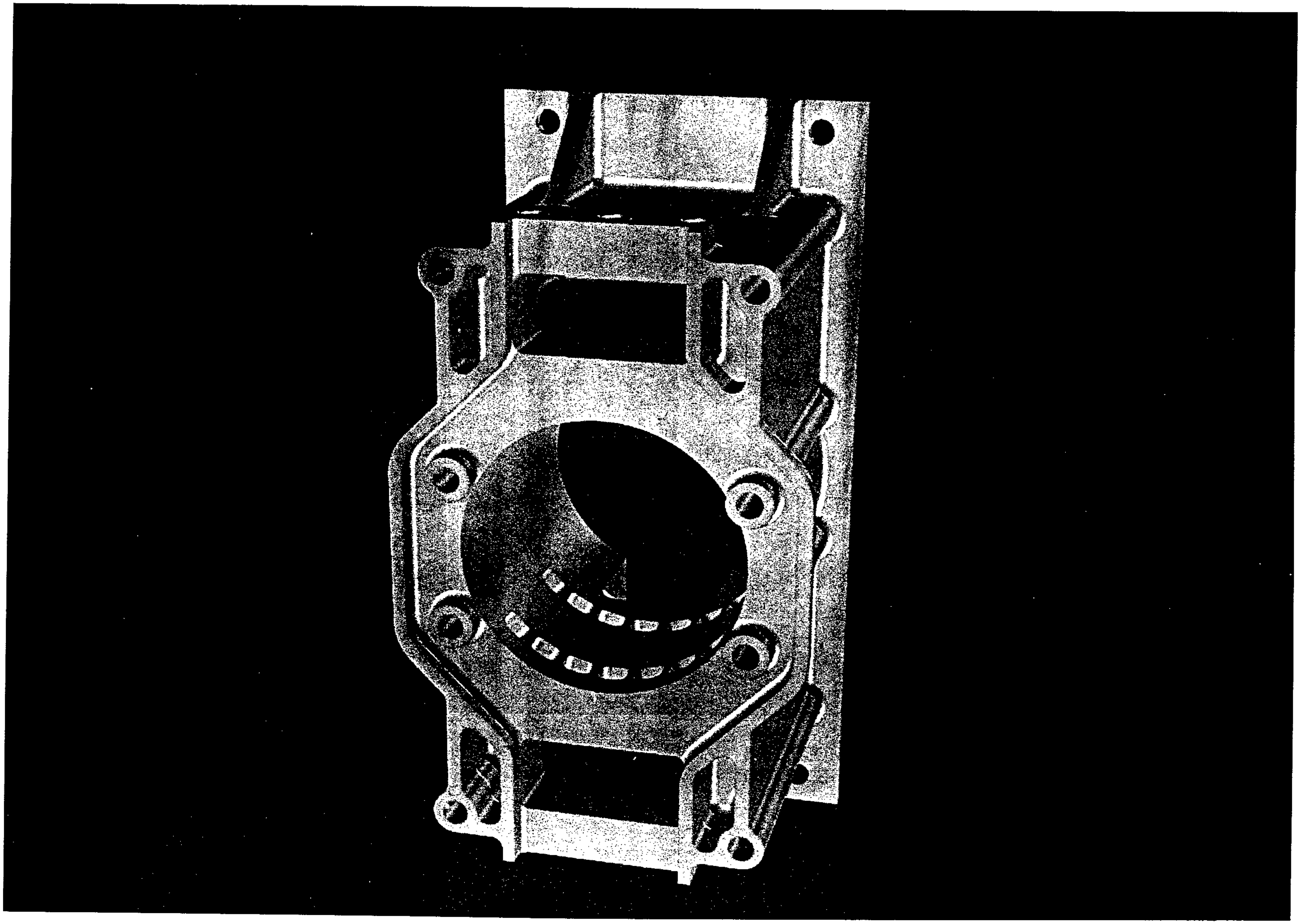
CS 710



University of Utah
Computer Science

AIRBOX SECTION THROUGH
CYLINDER BLOCK

CS 711



University of Utah
Computer Science

SECTION OF THE INTAKE
OF THE CYLINDER BLOCK

CS 712

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

COST REPORTING SUMMARY AND DETAIL

FY	Proj.No	PROJECT TITLE	Mod. No.	DARPA	MATCH	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
94	CS-AR94-01	**Running Chassis II Amerigon**		700,000	720,000	X	12/31/96		628,222
94	CS-AR94-02	**M300DC Motor Speed Controller Jefferson Programmed Power**		217,000	217,000	X	07/10/96	09/20/96	217,000
94	CS-AR94-03	**HD Hybrid Electric Drive Train SBAPCD**		29,568	9,856	X			29,568
94	CS-AR94-04	**Distributed Energy Management System Hughes Technical Services Company**		250,000	485,000				
94	CS-AR94-05	**HEV Battery System Bolder Tech**							0
94	CS-AR94-06	**Catalytic Combuster/Hybrid Electric Bus Capstone**		300,000	300,000	X	12/30/96		268,250
94	CS-AR94-07	**Hybrid Electric Air Emission Study NRDC/ACUREX**		100,000	100,000	X	11/01/96		63,000
94	CS-AR94-08	**Program Management CALSTART**		369,000					369,000
94	CS-AR94-09	**Project Hatchery North CALSTART**	0003	150,000	135,000				150,000
94	CS-AR94-10	**NAS Planning Grant CALSTART**	0003	250,000					250,000
94	CS-AR94-12	**Data Acquisition CALSTART**		150,000					150,000
94	CS-AR94-13	**Energy Management Controller DELCO/Hughes Aircraft**		18,000				08/01/95	18,000
94	CS-AR94-94	Funds Pending Re-allocation		1,280,432					
94	CS-AR94-11	CALSTART Internet Project		90,000					
94 Total				**3,904,000**	**1,966,856**				**2,143,040**

FY	Proj.No	PROJECT TITLE	Mod. No.	DARPA	MATCH	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
95	CS-AR95-01	**Flywheel Mag Loss Min Bearing AVCON**	0004	126,349	126,349	X	06/15/94		53,926
		Flywheel Life-Cycle Testing Battery							
95	CS-AR95-02	**US Flywheel**	0004	400,000	1,600,000	X	05/07/96		366,257
95	CS-AR95-03	**Compact Low Cost Relays Coriolis**	0004	100,000	100,000				
95	CS-AR95-04	**Alturdyne Rotary Engine/Bus Demo Advanced Propulsion Systems**	0004	65,000					0
95	CS-AR95-05	**Safe Electro-Mechanical Batteries Rockwell**	0004	259,500	783,000	X	09/30/96		173,156
95	CS-AR95-06A	**Adv. Hybrid Recon Propulsion System Rod Millen Motorsport**	0004	316,149		X	02/28/97		316,149
95	CS-AR95-06B	**Adv. Hybrid Recon Propulsion System AeroVironment**	0004	583,854	91,492	X	08/15/97		525,464
95	CS-AR95-07	**Rotapower Engine Moller International**	0004	201,850	217,320	X	02/04/97		200,342
95	CS-AR95-99	**Program Management**	0004	203,394					203,394
95 Total				**2,256,096**	**2,918,161**				**1,838,688**

FY	Proj.No	PROJECT TITLE	Mod. No.	DARPA	MATCH	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
96	CS-AR96-01	**Quick Charging Systems Trinity**	P00008	553,088	556,596	X	06/30/98		64,085
96	CS-AR96-02	**High Efficiency Air-Conditioning Glacier Bay**	P00007	235,000	190,000	X	04/10/98		107,649
96	CS-AR96-04	**E/HEV Manufacturability CALSTART**	P00007						
96	CS-AR96-05	**Prototype Hybrid Electric Truck ISE**	P00007	250,000	496,700	X	07/10/98		100,000
96	CS-AR96-06	**EV Range Extender AC Propulsion**	P00007	170,000	170,000	X	04/10/98		153,000
96	CS-AR96-07	**Purpose Built EV Engineering Pivco**	P00007	150,000	350,000				
96	CS-AR96-08	**Distributed Energy Mgmt System Hughes Technical Services Company**	P00007	250,000	123,000		03/30/97		
96	CS-AR96-09A	**Adv HE Recon Veh AeroVironment**	P00007	359,712		X			68,424
96	CS-AR96-09B	**Adv HE Recon Veh Rod Millen**	P00007	270,304	36,000	X	03/30/98		108,442
96	CS-AR96-10	**Program Management CALSTART**	P00007	188,502					116,983
96	CS-AR96-96	Pending Re-allocation for HEV Study		200,000					
96 Total				**2,626,606**	**1,922,296**				**718,583**
97A	CS-AR97A-02	**Assessment of Advanced Engine Technologies for UAV and HEV Applications FEV ENGINE TECH.**	P00009	1,000,000	1,000,000				
97A	CS-AR97A-03	**Fuel Injector for UAV and HEV Engine Corporation of America**	P00009	245,000	245,000				122,500
97A	CS-AR97A-99	**Program Management CALSTART**	P00009	124,500					
97A Total				**1,369,500**	**1245000**				**122,500**
97B	CA-AR97B-01	**Heavy Fuel Engine Test - General Atomics**	P00011	500,000	500,000				
97B	CS-AR97B-99	**Program Management - CALSTART**	P00011	50,000					
97B	CA-AR97B-04	**Internet Program - CALSTART**	P00011	90,000					
97B Total				**550,000**	**500,000**				**0**
Grand Total				**10,706,202**	**8,552,313**				**4,822,811**

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR94-01	1	Initiate work	200,000	460,000	1	11/14/95	11/21/95	75,000
CS-AR94-01	2	Complete breadboard designs of drive train, running chassis, steel space frame	175,000	200,000	2	12/31/95	12/15/95	103,222
CS-AR94-01	3	Fabricate EV4 & BEV prototype parts Revise design pakgs	125,000	0	3	3/31/96		
CS-AR94-01	4	Complete all BEV vehicle tests. Revise tools.	40,000	15,000	4	6/30/96	7/8/96	270,000
CS-AR94-01	5	Complete build of EV4. Complete EV4 tests.	0	0	5	9/30/96		36,000
CS-AR94-01	6	Complete (begin tests) first productionized drive train.	0	0				
CS-AR94-01	7	Complete Finite Element Analysis and design of running chassis BEV.	0	0				
CS-AR94-01	8	Complete build of 4 alum BEV's w/o body panels - 2 welded frames. Complete build/test 5 productionized drive trains. Complete comparative analysis. Complete final report.	160,000	45,000	6	12/31/96		144,000
CS-AR94-01 Total			700,000	720,000				628,222
CS-AR94-02	1	Design complete	72,000		1	10/10/95	10/25/95	72,000
CS-AR94-02	2	CPU Logic Board operational	65,000	80,000	2	1/10/96	1/11/96	65,000
CS-AR94-02	3	1st prototype controller test	50,000	60,000	3	4/10/96	4/17/96	58,300
CS-AR94-02	4	Final report	30,000	77,000	4		9/20/96	21,700
CS-AR94-02 Total			217,000	217,000				217,000

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR94-03		No milestone - program canceled	29,568	9,856	X	6/15/95		29,568
CS-AR94-03 Total			29,568	9,856				29,568
CS-AR94-04	1	Delco - See CS-AR96-08 Requirements defined; concept for controller hardware defined	30,000	50,000	1	6/30/96	6/30/96	
CS-AR94-04	2	Software defined/programmed	30,000	50,000	2	9/30/96	9/30/96	
CS-AR94-04	3	Design/Implementation of multiple pack system controller	70,000	370,000	3	12/31/96	12/31/96	
CS-AR94-04	4	Software installed on charge system	50,000	15,000	4	3/30/97	3/30/97	
CS-AR94-04	5	Bluebird Buses equipped; Field data acquired; DEMS upgrade concept complete/controller built	70,000		5			
CS-AR94-04 Total			250,000	485,000				0
CS-AR94-05		No milestone - program canceled						
CS-AR94-05 Total			0	0				0
CS-AR94-06	0	Initiate work	40,000	40,000		8/30/95	12/15/95	36,000
CS-AR94-06	1	Vandenburg Combuster/Monolith Test Rig	102,500	102,500		12/31/95	1/11/96	92,250
CS-AR94-06	1	Hardware/Electrical Designs	50,000	50,000	1	12/31/96	1/11/97	50,000
CS-AR94-06	2	Vehicle Integration	80,000	80,000	2	3/30/97	3/30/97	90,000
CS-AR94-06	3	System Integration	20,000	20,000	3	6/20/97		

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR94-06	4	Final report	7,500	7,500	4	9/30/97		
CS-AR94-06 Total			300,000	300,000				268,250
CS-AR94-07	1	Refine study design.	20,000	20,000	1	8/1/95	12/30/95	
CS-AR94-07	2	Data collection	16,000	16,000	2	11/1/95	9/30/96	
CS-AR94-07	3	Data evaluation	16,000	16,000	3	2/1/96	12/30/96	63,000
CS-AR94-07	4	Scientific review	16,000	16,000	4	5/1/96		
CS-AR94-07	5	Draft study	16,000	16,000	5	8/1/96		
CS-AR94-07	6	Final report/study	16,000	16,000	6	11/1/96		
CS-AR94-07 Total			100,000	100,000				63,000
CS-AR94-08		Program Management CALSTART	369,000					369,000
CS-AR94-08 Total			369,000	0				369,000
CS-AR94-09		Hatchery North	150,000	135,000				150,000
CS-AR94-09 Total			150,000	135,000				150,000
CS-AR94-10		NAS Planning	250,000					250,000
CS-AR94-10 Total			250,000	0				250,000
CS-AR94-11		Internet Demo	90,000					
CS-AR94-11 Total			90,000	0				0

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR94-12	1	Feasibility Study	16,271		1	09/30/95	09/30/95	16,271
CS-AR94-12	2	Schematic/Housing for keyboard/display	10,000		2	12/31/95	12/31/95	9,957
CS-AR94-12	3	Establish internet connection	20,608		3	03/30/96	03/30/96	20,608
CS-AR94-12	4	Hardware Test Box for Analog/digital boards	54,077		4	06/30/96	06/30/96	54,077
CS-AR94-12	5	DC Converter Schematics. Build Prototype	16,666		5	09/30/96	09/30/96	21,700
CS-AR94-12	6	Second PCB. Testing CDAS & Installation	32,378		6	12/31/96	12/31/96	27,387
CS-AR94-12	7	Testing complete			7	03/30/97	03/30/97	
CS-AR94-12	8	Final report			8	06/30/97	06/30/97	
CS-AR94-12 Total			150,000	**0**				150,000
CS-AR94-13		DELCO/Hughes Energy Mgmt Cont	18,000					18,000
CS-AR94-13 Total			18,000	**0**				18,000
CS-AR94-94		Proposals Pending	1,280,432					
CS-AR94-94 Total			1,280,432	**0**				0
94 Total			**3,904,000**	**1,966,856**				**2,143,040**

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR95-01	1	Computer model, Rotordynamic Analysis,	37,706	37,706	1	9/30/96	10/15/96	37,706
CS-AR95-01	2	Complete rotordynamic analysis	16,220	16,220	2	12/31/96	12/31/96	16,220
CS-AR95-01	3	Complete Test Plan, begin fabrication of test	10,160	8,470	3	3/30/97		
CS-AR95-01	4	Complete fabrication of test rig	15,160	8,600	4	6/30/97		
CS-AR95-01	5	Fabricate standard bearing	12,182	23,618	5	9/30/97		
CS-AR95-01	6	Test Standard Bearing	10,124	8,600	6	12/31/97		
CS-AR95-01	7	Test Optimized bearing, Iterate computer	3,797	12,800	7	3/31/98		
CS-AR95-01	8	Final report	21,000	10,335	8	6/30/98		
CS-AR95-01 Total			126,349	126,349				53,926
CS-AR95-02	1	Detail plan		900,000	1	7/7/96		
CS-AR95-02	2	Fabricate flywheels	230,000	300,000	2	9/7/96	7/16/96	195,200
CS-AR95-02	3	Design, prog. & fabricate DAS	90,000	140,000	3	9/7/96	12/2/96	171,057
CS-AR95-02	4	Design/Install containment chambers	50,000	80,000	4	9/7/96	12/30/96	
CS-AR95-02	5	Install modules/check system		60,000	5	10/7/96		
CS-AR95-02	6	Cycle tests/statistical analysis	20,000	80,000	6	3/7/97		
CS-AR95-02	7	Final report	10,000	40,000	7	6/7/97		
CS-AR95-02 Total			400,000	1,600,000				366,257
CS-AR95-03	1	Coriolis	100,000	100,000				
CS-AR95-03 Total			100,000	100,000				0

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR95-04	1	Alturdyne bus demonstration	65,000		1			
CS-AR95-04 Total			65,000	0				0
CS-AR95-05	1	Containment ring design	50,000	552,000	1	12/31/96	12/31/96	63,472
CS-AR95-05	2	Containment ring fabrication	75,000	77,000	2	3/30/97		97,463
CS-AR95-05	3	Assembly checkout/test	100,000	77,000	3	6/30/97		12,221
CS-AR95-05	4	Final report	34,500	77,000	4	9/30/96		
CS-AR95-05 Total			259,500	783,000				173,156
CS-AR95-06A	1	Initiate work	75,000		1	4/1/96		75,000
CS-AR95-06A	2	Suspension/Differential Dev	60,287		2	4/30/96		13,881
CS-AR95-06A	3	Design review	60,287		3	6/30/96		59,688
CS-AR95-06A	4	4 Suspension design	60,287		4	9/30/96		75,894
CS-AR95-06A	5	5 Final report	60,288		6	2/28/97		91,686
CS-AR95-06A Total			316,149	0				316,149
CS-AR95-06B	1	Battery Mgmt Final report; Inverter repkg	309,974	53,972	1	9/31/96	9/31/96	309,974
CS-AR95-06B	2	DC-DC Converter Design; cell specs rpt; 2	215,495	37,520	2	12/31/96	12/31/96	215,490

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR95-06B	3	Fianl report	58,385		3			0
CS-AR95-06B Total			583,854	91,492				525,464
CS-AR95-07	1	Complete design	40,000	108,320	1	3/6/96		40,000
CS-AR95-07	2	Order batteries/tooling	57,855		2	3/30/96	5/31/96	53,162
CS-AR95-07	3	Finish block fabrication	25,000	46,500	3	5/15/96		38,490
CS-AR95-07	4	Receive/Evaluate Geo Metro	16,495		4	8/16/96		46,201
CS-AR95-07	5	Drivetrain/Engine Installation	37,500	37,500	5	10/4/96	12/30/96	22,489
CS-AR95-07	6	Vehicle testing	15,000	15,000	6	12/15/96		
CS-AR95-07	7	Final report and additional funds	10,000	10,000	7	2/4/97		
CS-AR95-07 Total			201,850	217,320				200,342
CS-AR95-99		Program Management CALSTART	203,394					203,394
CS-AR95-99 Total			203,394	0				203,394
95 Total			2,256,096	2,918,161				**1,838,688**

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR96-01	0	Initiate work	64,085	7,200		1/30/97	1/30/97	64,085
CS-AR96-01	1	Flywheel/Interface/FESS/LIU Specifications	119,298	45,600	1	3/30/97		
CS-AR96-01	2	Design review/initial testing	116,791	88,400	2	6/30/97		
CS-AR96-01	3	Manufacture/Phase 1 testing	37,895	320,146	3	9/30/97		
CS-AR96-01	4	Installation drawings/program review	137,618	28,800	4	12/31/97		
CS-AR96-01	5	Integration and inital check-out		33,900	5	3/30/98		
CS-AR96-01	6	Final report	77,401	32,550	6	6/30/98		
CS-AR96-01 Total			553,088	556,596				64,085
CS-AR96-02	1	Initiate work	20,000			10/25/96		20,000
CS-AR96-02	2	Design of Major Components	34,573	44,113	1	12/31/96	12/31/96	34,573
CS-AR96-02	3	Prototype drawings complete	55,000	60,000	2	3/31/97	3/31/97	53,076
CS-AR96-02	4	Production of major components	50,000	45,000	3	6/30/97		
CS-AR96-02	5	Prototype bench testing	17,000	21,000	4	9/30/97		
CS-AR96-02	6	Production/Testing prototypes	35,000	8,000	5	12/31/97		
CS-AR96-02	8	Final report	23,427	11,887	7	3/31/98		
CS-AR96-02 Total			235,000	190,000				107,649
CS-AR96-04		EV Manufacturability Canceled						
CS-AR96-04 Total			0	0				0
CS-AR96-05	1	Drive system design approved. System	30,000	96,700	1	1/10/97	1/10/97	30,000
CS-AR96-05	2	System controller modules design.	35,000	100,000	2	4/10/97	3/30/97	35,000
CS-AR96-05	3	Vehicle integration plan complete	35,000	75,000	3	7/10/97	3/30/97	35,000
CS-AR96-05	4	Major components integrated	30,000	50,000	4	10/10/97		
CS-AR96-05	5	Vehicle fully integrated/testing initiated	30,000	75,000	5	1/10/98		
CS-AR96-05	6	Phase 1 Operational testing complete	30,000	50,000	6	4/10/98		
CS-AR96-05	7	Commercialization plan initiated	30,000	25,000	7	7/10/98		
CS-AR96-05	8	Phase 2 testing complete/Business plan	5,000	25,000	8	10/10/98		
CS-AR96-05	9	Final report	25,000		9	1/10/99		
CS-AR96-05 Total			250,000	496,700				100,000

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR96-06	1	Design study complete	51,000	57,000	1	1/10/97	2/21/97	51,000
CS-AR96-06	2	Prototype charging system constructed	72,000	53,000	2	4/10/97		72,000
CS-AR96-06	3	Moller engine delivered	22,000	25,000	3	7/10/97		30,000
CS-AR96-06	4	Integration complete	8,000	11,000	4	10/10/97		
CS-AR96-06	5	Testing complete	8,000	15,000	5	1/10/98		
CS-AR96-06	6	Final report	9,000	9,000	6	4/10/98		
CS-AR96-06 Total			170,000	170,000				153,000
CS-AR96-07	1	Design analysis against FMVSS & SAE	80,000	180,000	1			
CS-AR96-07	2	Complete door-re-engineering/prototypes	40,000	95,000	2			
CS-AR96-07	3	FMSS door side impact test. Release door for manufacturing	15,000	40,000	3			
CS-AR96-07	4	4 US Suppliers components list. FMVSS	15,000	35,000	4			
CS-AR96-07 Total			150,000	350,000				0
CS-AR96-08	5	Bluebird Buses equipped; Field data acquired; DEMS upgrade concept	200,000	108,000	5	6/30/97		
CS-AR96-08	6	Final report	50,000	15,000	6	9/30/97		
CS-AR96-08 Total			250,000	123,000				0

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR96-09A	1	Quarterly report; battery selection	69,282		1	12/31/96	12/31/96	68,424
CS-AR96-09A	2	Transmission analysis	72,727		2	3/30/97		
CS-AR96-09A	3	Battery Progress report	92,727		3	6/30/97		
CS-AR96-09A	4	1-2 speed trans report	74,066		4	9/30/97		
CS-AR96-09A	5	Battery test report	50,910		5	12/31/97		
CS-AR96-09A Total			359,712	**0**				68,424
CS-AR96-09B	1	Initiate work	38,614		1	9/30/96	9/30/96	38,614
CS-AR96-09B	2	Test platform support	38,615		2	12/31/96	12/31/96	8,361
CS-AR96-09B	3	ADC fabrication	38,615		3	3/30/97		42,962
CS-AR96-09B	4	ADC testing	38,615	10,000	4	6/30/97		18,505
CS-AR96-09B	5	ADC integrated JTEV	38,615	10,000	5	9/30/97		
CS-AR96-09B	6	Algorithms refined	38,615	10,000	6	12/31/97		
CS-AR96-09B	7	Test complete/Final report	38,615	6,000	7	3/30/98		
CS-AR96-09B Total			270,304	36,000				108,442
CS-AR96-10	1	Program Management CALSTART	188,502					116,983
CS-AR96-10 Total			188,502	**0**				116,983
CS-AR96-96		Proposals Pending	200,000					
CS-AR96-96 Total			200,000	**0**				0
96 Total			**2,626,606**	**1,922,296**				**718,583**

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR97A-02	1	TECE Thermo/Mech Assessment	300,000	100,000				
CS-AR97A-02	2	2/4 Stroke Concept Assessment	220,000	200,000				
CS-AR97A-02	3	2/4 Stroke Demo	480,000	700,000				
CS-AR97A-02 Total			1,000,000	1,000,000				0
CS-AR97A-03	1	1.0 Completion and submission of program plan	122,500	0				122,500
CS-AR97A-03	2	1.1 Overall Engine Design, 1.2 Engine Thermal Cycle Analysis,1.1 Coordination of Analytical Effort with FEV, 2.1 ECA Fuel Injector Design,2.2 Fuel Injuector Options Assessment, 2.3 Coordinated Fuel Injection Review	122,500	245,000				
CS-AR97A-03 Total			245,000	245,000				122,500
			1,245,000	1,245,000				**122,500**

Proj. No	Mile. No.	PROJECT TITLE AND NUMBER	DARPA	MATCHING	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
CS-AR97B-01	1	Progress of sub-system testing, review of engine test facilities and plan for testing of advanced powerplant subsystem.	0	50,000				
CS-AR97B-01	2	Powerplant integrated to existing dynamometer. Subsystem test complete.	0	75,000				
CS-AR97B-01	3	Completion of low altitude simulation system. Completion of renovations. Commissioning of new propeller stand facility. Systems function - basic series. Systems optimization completed for baseline. Sea level mapping complete.	300,000	300,000				
CS-AR97B-01	4	Powerplant integrated to propeller test stand. Low altitude simulation mapping complete. Propstand limited durability demonstrated.	50,000	75,000				
CS-AR97B-01	5	Continued Progress	50,000	0				
CS-AR97B-01	6	Continued Progress	50,000	0				
CS-AR97B-01	7	Demonstrated fuel injection durability maturation.	50,000	0				
CS-AR97B-01 Total			500,000	500,000				0
CS-AR97B-04	1	Upgrade CALSTART web server	30,000					
CS-AR97B-04	2	Expand Vehicle Catalog	20,000					
CS-AR97B-04	3	Develop component catalog	20,000					
CS-AR97B-04	4	Develop AT Industry FAQ	20,000					
CS-AR97B-04 Total			90,000	0				0
CS-AR97B-99		Program Management CALSTART	50,000					
CS-AR97B-99 Total			50,000	0				0
97B TOTAL			550,000	500,000				0
Grand Total			**10,706,202**	**8,552,313**				**4,822,811**

CALSTART

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

Completed Projects

PROGRAMMABLE DC CONTROLLER

Project Manager: ***Jefferson Programmed Power***

CS-AR94-02

	MILESTONES	DARPA	MATCH	QTR	DATE DUE	DATE COMPLETE	DARPA FUNDS EXPENDED
1	Design complete	72,000		1	10/10/95	10/25/95	72,000
2	CPU Logic Board operational	65,000	80,000	2	1/10/96	1/11/96	65,000
3	1st prototype controller test	50,000	60,000	3	4/10/96	4/17/96	58,300
4	Final report	30,000	77,000	4	6/30/96	9/20/96	21,700
	CS-AR94-02 TOTALS	217,000	217,000				217,000

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

Canceled Projects

OPTIMIZED 30kW TURBINE/FLYWHEEL HYBRID ELECTRIC VEHICLE

Project Manager: ***Rosen Motors***

ALUMINUM RUNNING CHASSIS FOR CIVILIAN USE (RCP-4C)

Project Manager: ***Amerigon Incorporated***

ALUMINUM RUNNING CHASSIS FOR MILITARY USE (ARC4-M)

Project Manager : ***Amerigon Incorporated***

HYBRID ELECTRIC BATTERY

Project Manager: ***Bolder Technologies***
CS-AR94-05

HEAVY-DUTY HYBRID ELECTRIC DRIVE TRAINS

Project Manager: ***Santa Barbara Air Pollution Control District***
CS-AR94-03

	MILESTONE	DARPA	MATCH		DARPA FUNDS EXPENDED
CS-AR94-03	No milestone - program canceled	29,568	9,856		29,568
		29,568	9,856		29,568

Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
and modifications through P00011
Quarterly Report
July 1 to September 30, 1997

ELECTRIC AIRPORT SHUTTLE BUSES

Project Manager: ***Santa Barbara Air Pollution Control District***

ENERGY MANAGEMENT CONTROLLER

Project Manager: ***Delco Electronics***
CS-AR94-13

	DARPA	MATCH				DARPA FUNDS EXPENDED
CS-AR94-13	18,000					18,000
	18,000	0				18,000