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4 JUNE 1987

SCIENCE & TECHNOLOGY

JAPAN

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DEVELOPMENT OF TRANSPARENT ZIRCONIA CERAMICS DISCUSSED

Tokyo KINO ZAIRYO in Japanese Oct 86 pp 31-37

[Text] The fabrication of highly transparent zirconia ceramics has been difficult up to now; however, its fabrication became possible by adopting the new fabrication method which performs doping of titania. Since this transparent ceramic is easy to fabricate and possesses characteristics such as superior heat-resisting property, infrared transmitting property, and a high refractive index, applications for use as optical parts are considered in the future. Explanations will be made here briefly on the fabrication method and properties of transparent zirconia ceramics.

1. Introduction

Up to now, various transparent ceramics as shown in Table 1, as well as transparent alumina, have been developed. A report on transparent zirconia has already been made in 1967. Mazdhyasni used the powder synthesized from the hydrolysis of alkoxide and fabricated the ZrO_2 (6 mol percent Y_2O_3) ceramics by low temperature ($1,500^\circ C$) sintering. Moreover, Vahldiek, et al., fabricated the ZrO_2 (15 mol percent Y_2O_3) ceramics by means of an ultrahigh-pressure hot press (10,000 atmospheric pressure, $1,700^\circ C$). However, it has been reported that the light transmission of such transparent zirconias was about 10 to 15 percent, and therefore it was considered that it would be insufficient to use such transparent zirconias for optical ceramics.

In 1975 the so-called high strength, high tensile zirconia resulting from the new high tensile mechanism peculiar to zirconia was discovered. In recent years, it has been in the limelight as a new ceramic for engineering. With the appearance of this zirconia as the turning point, apparently research on the synthesis and physical properties of zirconia has become active all at once.

Backed by such research on zirconia of high tensility, it was discovered that highly transparent zirconia ceramics could be fabricated. Introduced here are the fabrication method and characteristics of the yttria zirconia ceramics which has improved its transparency tremendously by the addition of titania.

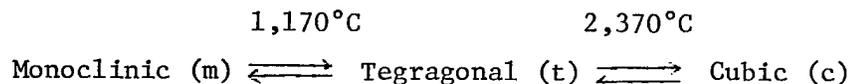
Table 1. Examples of Transparent Ceramics

Compound matters	Crystal system	Fabrication method	Reporter
Al ₂ O ₃	Hexagonal	MgO addition, H ₂ atmosphere	2
MgO	Cubic	LiF addition, hot press	3
MgAl ₂ O ₄	Cubic	H ₂ atmosphere	4
Mullite (3 Al ₂ O ₃ ·2SiO ₂)	Rhombic	Hot press	5
Y ₂ O ₃ (10 percent ThO ₂)	Cubic	ThO ₂ addition, H ₂ atmosphere	6
LiAl ₅ O ₈	Cubic	Hot press	7
PLZT	Pseudocubic	PbO, O ₂ atmosphere	8
Gd ₂ O ₃	Cubic	LiCl addition, hot press	9
Sialon (Si ₂ Al ₄ O ₄ N ₄)	Hexagonal	Hot press	10
AlN	Hexagonal	Ca(NO ₃) ₂ addition	11

2. Zirconia Containing Titania/Yttria

2.1. Y₂O₃-ZrO₂, TiO₂-ZrO₂ System Phase Diagram

Three crystal polymorphisms are present in zirconia.



In the t \longrightarrow m transition, the volume expansion of about 4 volume percent takes place. Due to the abnormal volume expansion accompanying this transition, a delicate sintering item was not available. Therefore, stabilizers such as CaO, MgO, and Y₂O₃ were subjected to solution treatment, the transition temperature to the m phase was lowered, and stabilizing the high temperature phase lowered to somewhere around room temperature had been conducted up to this time.

The Y₂O₃-ZrO₂ system phase diagram is shown in Figure 1. It can be seen that the c phase, the high temperature phase, extends to the low temperature. The stabilizer stabilizing the high temperature type c phase is called the stabilizing zirconia and the stabilizer that semistabilizes the t phase is called the tetragonal zirconia polycrystal (TZP). TSP indicates the martensitic type transition from t to m (t \longrightarrow m) by applying stress and by utilizing this, it becomes a ceramic of high tensility.

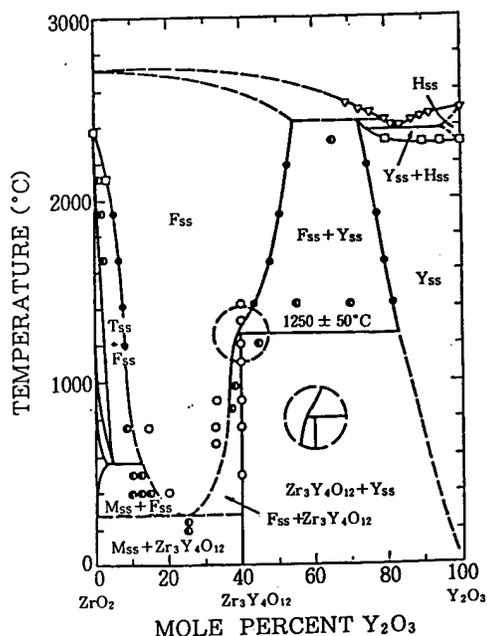


Figure 1. ZrO₂- Y₂O₃ System Phase Diagram

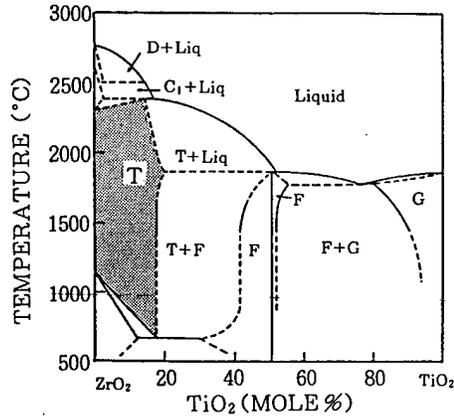
- M: Monoclinic zirconia
- T: Tetragonal zirconia
- F: Cubic zirconia

ZrO₂ containing Y₂O₃ has been widely used for oxygen sensors, thermistors, and ceramics for machine structures. However, ZrO₂ containing TiO₂ has been practically ignored to this time. According to the TiO₂-ZrO₂ system phase diagram shown in Figure 2, it can be seen that TiO₂ is subjected well to solution treatment in ZrO₂ at high temperature and is substituted in the tetragonal zirconia structure. The transition temperature from the t phase to the m phase lowers together with the added amount of TiO₂ and it can be presumed that the addition of TiO₂ has the action of stabilizing tetragonal zirconia. Moreover, there is also a report that TiO works as the sintering aiding agent of yttria zirconia. Therefore, interest has been held on TiO from the two viewpoints, effective as a stabilizer and sintering aiding agent.

2.2 TiO₂-Y₂O₃-ZrO₂ System

Figure 3 shows the reaction diagram that has been obtained by using TiO₂-Y₂O₃-ZrO₂ fine powder and sintering at 1,400°C. It became clear that TiO₂ was subjected to solution treatment up to about 20 mol percent in Y₂O₃-ZrO₂, this was possible in both structures of the c and t phases, and ZrTiO₄ was formed in more than 20 mol percent of TiO₂.

The effect placed on the grain growth when TiO₂ is added to the Y₂O₃-ZrO₂ system is shown in Figure 4. It shows the results of the 1,500°C ceramics



C₁ ; cubic ZrO₂ solid solution
 D ; ZrO₂ solid solution
 F ; ZrTiO₄ solid solution
 G ; TiO₂ solid solution
 T ; tetragonal ZrO₂ solid solution

Figure 2. ZrO₂-TiO₂ System Phase Diagram

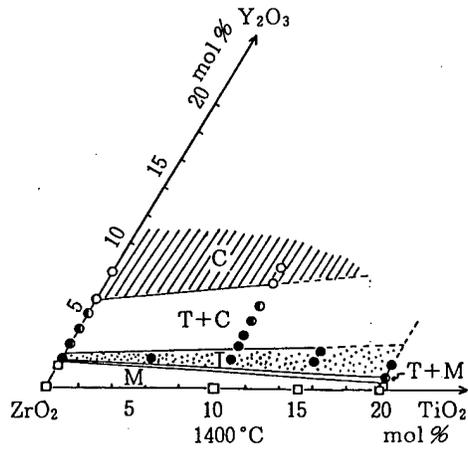


Figure 3. Reaction Diagram of ZrO₂-Y₂O₃-TiO₂ System at 1,400°C

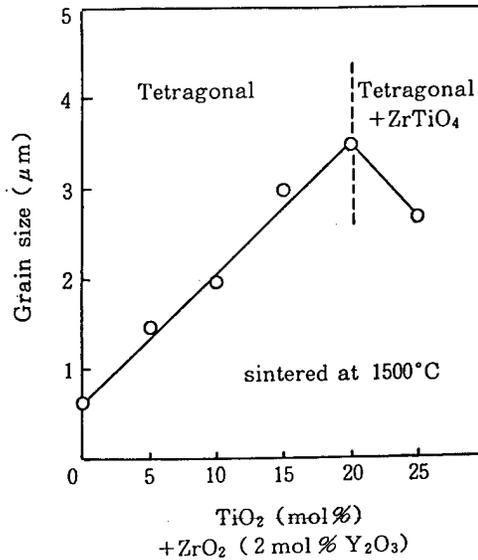


Figure 4. Relation Between the TiO₂ Amount Added and Grain Diameter

that added TiO₂ to ZrO₂ (2 mol percent Y₂O₃). It is clear that TiO accelerates a significant grain growth. In the TiO₂-Y₂O₃-ZrO₂ system, interest is keen in the tetragonal system containing zirconia as a zirconia of high tensility, but the transparency of cubic zirconia without optical anisotropy is superior. Introduction, therefore, will be hereinafter made mainly on the TiO₂-Y₂O₃-ZrO₂ system cubic zirconia.

3. Fabrication Method of Transparent Zirconia

3.1. Powder Preparation

Wet methods, such as the neutralization coprecipitation method, hydrolysis method, and alkoxide method are well known as the synthesizing method of easy sintering zirconia fine powder. Titanium alkoxide was added here to the Y₂O₃-ZrO₂ system fine powder synthesized by hydrolysis method and fine powder obtained by sintering was used.

3.2 Fabrication of Ceramics

Transparent zirconia ceramics is fabricated by either atmospheric sintering only or the combination of atmospheric sintering and hot hydraulic press (HIP) treatment. The flow diagram for fabricating ceramics is shown in Figure 5. When using the atmospheric sintering method, a specimen with good transparency is made available by maintaining the temperature at above 1,600°C. A specimen further excelling in transparency is available by the HIP treatment on atmospheric sintered ceramics. The HIP treatment has been set at the temperature of above 1,500°C and at the atmospheric pressure of above 500. By performing the HIP treatment, the specimen is blackened.

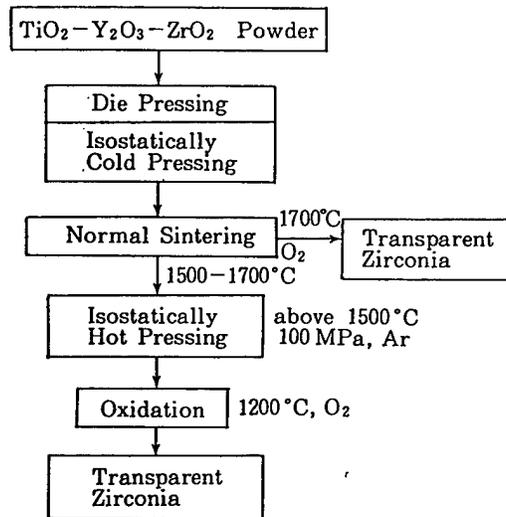


Figure 5. Fabrication Process Diagram

The reason for this blackening is presumed to be caused by the increase of oxygen deficiency and the accompanying valency change generated on Zr and Ti as the specimen was left in a deoxidating condition in the argon. The blackened specimen is oxidized and becomes transparent ceramics by sintering in air of more than 1,000°C. One of the big characteristics of this combination method of atmospheric sintering and HIP treatment is that a specimen with a high transparency is attainable at a temperature of about 1,600°C and the low fabrication temperature.

4. Properties of Transparent Zirconia

4.1. Texture of Ceramics

An example of transparent zirconia ceramics is shown in Photo 1 [omitted]. This specimen is ZrO_2 (8 mol percent Y_2O_3) containing TiO_2 (10 mol percent). The characteristics of this transparent zirconia with a representative composition is shown in Table 2. For the sake of comparison, indication was also made on ZrO_2 (8 mol percent Y_2O_3) with no addition of TiO_2 . The crystal phase of both types is cubic crystal but ceramic density slightly reduces when adding TiO_2 . The ceramic texture of TiO_2 10 mol percent addition (A-4) and the TiO_2 non-added (B-1) specimens is shown in Photo 2 [omitted]. By adding TiO_2 , the grain size becomes more than 100 μm , the number of air holes decreases simultaneously with significant grain growth and it is presumed that these changes link to the cause of becoming highly transparent. Moreover, the presence of a grain boundary glass phase was not recognized in the observatory results through a transmission type electron microscopic photo.

Table 2. Characteristics of TiO₂-Y₂O₃-ZrO₂ Ceramics

Sample	Composition		Fabrication Method	Grain Size (μm)	Density (cm ³ /g)	Phase Content
	Y ₂ O ₃ /ZrO ₂ (mol%)	TiO ₂ /ZrO ₂ +Y ₂ O ₃ (mol%)				
A-1	8/92	10/90	*S(1430°C, 12h)	20	5.87	Cubic
A-2	"	"	" **HIP	20~30	"	"
A-3	"	"	S(1630°C, 7h)	100~200	"	"
A-4	"	"	→HIP	"	"	"
B-1	8/92	0/100	S(1630°C, 7h)→HIP	40~60	5.98	Cubic

*S: Sintering; **HIP: 1,500°C, 100 MPa, Ar

4.2 Light Transmittivity

The linear transmittivity for the visible rays of the specimens shown in Table 2 is as indicated in Figure 6. Moreover, the infrared transmittivity is shown in Figure 7. It can be understood from the results obtained in Figure 6 that the transparency of the TiO₂ added specimen is far superior in comparison to the transparency of the TiO₂ nonadded specimen, transmittivity increases when the sintering temperature is increased and the grain size is enlarged, and the transmittivity further increases by conducting HIP treatment. Since the theoretical transmittivity of this material is presumed to be about 70 percent, about 90 percent of the incoming light will be transmitted for a material with the highest transparency when the thickness is 0.73 mm. From the results obtained in Figures 6 and 7, it became clear that the visible and infrared rays possessing wavelength of 0.35 to 6 μm can pass through this ceramic.

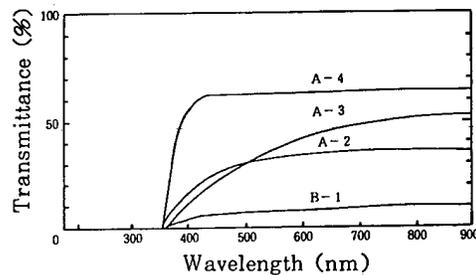


Figure 6. Light Transmittivity of Transparent Zirconia

4.3. Fluorescent Radiation Characteristics

By doping a small amount of rare earth oxide such as Eu₂O₃ and Tb₂O₃ to the transparent zirconia ceramics, fluorescent radiation characteristics can be provided by ultraviolet irradiation. The specimen doped with Eu₂O₃ radiates a red fluorescence and the specimen doped with Tb₂O₃ radiates a green fluorescence.

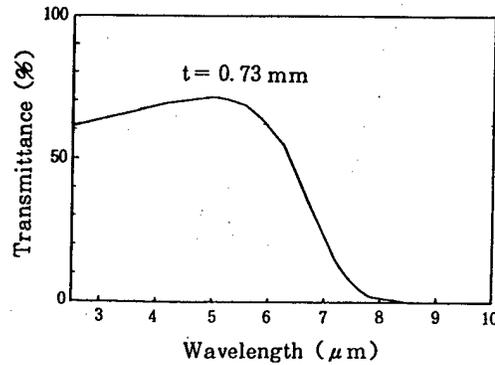


Figure 7. Infrared Transmittivity of Transparent Zirconia

4.4 Mechanical Properties

Ceramics showing high transparency is a texture consisting of cubic grains and the mechanical properties such as bending strength and tensility that are not as good in comparison to the high tensile ceramics consisting of tetragonal texture. As an example, results have been obtained on specimen A-4 of Table 2 that the room temperature strength degree of bending is 210 MPa and the Vickers hardness is 12 GPa. By reducing the Y_2O_3 amount and including the tetragonal grains, with the introduction of reinforcing mechanism by stress inductive transformation, mechanical properties can be improved. However, the transparency decreases at the same time. Resolving this problem is the big issue for the future.

5. Application Possibilities

Shown in Table 1 are the various transparent ceramics that have been developed up to now. Among the developed ceramics, those consisting of cubics without an optical anisotropy became the highly transparent ceramics. In the oxide system, rare earth oxides such as MgO and $MgAl_2O_3$ and Y_2O_3 are known. The transparent zirconia introduced here is far cheaper in comparison to rare earth oxides and excels in chemical stability in comparison to MgO. Since the fabrication method is either atmospheric sintering or atmospheric sintering plus HIP, complicated type and large-sized products would become readily available.

The characteristics of transparent zirconia are shown in Table 3. The transparent zirconia has the general properties possessed by zirconia besides just transparency. The adiabatic action resulting from the low heat conductivity, the superior bonding property with metal resulting from high coefficient of thermal expansion, and the oxygen ion conductivity can be listed as the properties peculiar to zirconia. In comparison to glass, it has characteristics such as being rich in heat-resisting property, the refractive index being high, and transmits infrared rays of long wavelength. Therefore, utilization for high temperature windows, reaction tubes, optical parts, and infrared transmitting parts is being considered.

Table 3. Characteristics of Transparent Zirconia Ceramics

-
- (1) Transparency (visible and infrared domains of 0.35 to 6 μm)
 - (2) High refractive index (n_D 2.2 to 2.4)
 - (3) Heat-resisting property (m.p. to 2,500°C)
 - (4) Adiabatic property (low heat conductivity 0.007 cal/cm°C sec)
 - (5) Coefficiency of thermal expansion great and close to metals (9 to 10 x 10⁻⁶/°C)
 - (6) Corrosion resistance
 - (7) High in hardness (Hv up to 1,200)
 - (8) Oxygen ion conductivity (10⁻²/Ωcm)
-

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20158/9365

CSO: 4306/3670

VIBRATION TEST OF 1/5 SCALE H-II ROCKET MODEL DESCRIBED

Tokyo KOCIKEN NYUSU in Japanese Aug 86 pp 2-3

[Text] The H-II rocket is under development with the target set for the launching of test vehicle No 1 in the winter of fiscal 1991. At the time of rocket launching and during its flight, vibration from various sources occurs in the airframe. The important items that should be established in the initial stage of the rocket development, such as the design load of rocket, environmental conditions of equipment on board, and design conditions of attitude control system, are dependent on the preliminary estimate of this airframe vibration. An accurate estimate is important for the development of a high-performance rocket.

The estimate of vibration characteristics of the airframe is conducted by vibration analysis programs such as the finite element method. It is necessary to make a vibration model based on a design drawing of the airframe. The accuracy of the analysis is determined by the accuracy of the model. Even the analysis method itself has problems of accuracy, and to evaluate the validity and accuracy of the analysis results without conducting tests on such a complicated structure as the H-II rocket entails great risk. Thus, in developing a new large rocket like this, it is necessary to confirm the validity of the analysis results by conducting a vibration test on a scale model. The H-II rocket is 48.3 meters in total length and weighs 255 tons, but the vibration model is on a one-fifth scale (9.65 meters in total length, 2.04 tons in weight). The larger the size of the model, the higher its accuracy becomes. However, since there are restrictions as to manufacture, handling, cost, etc., this model has been prepared on a one-fifth scale by taking into account the size of this laboratory's rocket vibration test equipment.

This test was conducted from fiscal 1985 to fiscal 1986 in joint research with the National Space Development Agency, using test equipment prepared for the full-plane ground vibration test of the STOL experimental aircraft "Asuka." These test results will be reflected in the basic design of the H-II rocket tests to be conducted in fiscal 1986.

20150/9274

CSO: 4306/2471

RESEARCH ON CATALYST COMBUSTION FOR GAS TURBINE

Tokyo KOGIKEN NYUSU in Japanese Aug 86 pp 3-4

[Article by Shigeru Hayashi, Aircraft Environmental Pollution Research Group]

[Text] In Japan, too, the range of uses of the gas turbine has expanded to other fields besides aircraft such as large-capacity composite electricity generation and dual-purpose electricity and steam generation, and thus demands for the purification of gas turbine exhaust are expected to increase. The gas turbine is referred to as a clean motor, but because of its high-temperature high-pressure combustion, its discharge of nitrogen oxides (NOx), which have a close connection with photochemical smog and acid rain, is several times higher than in the boiler now controlled by regulations. There are special conditions of the gas turbine that the cost of exhaust gas denitration is high because of its large amount of exhaust and a high concentration of residual oxygen in its exhaust. Furthermore, the effort to raise temperature and pressure for improving the fuel consumption results in an increase of nitrogen oxides so far as the present combustion system is adopted. Thus there is increased expectation for a new NOx combustion technology.

Now, reviewing the history of the gas temperature of the present gas turbine combustor, as shown in Figure 1, its gas reaches a high temperature exceeding 2,000° C and thereafter, it mixes with diluted air and drops to the turbine temperature. Could the maximum gas temperature in the combustor be lowered to less than about 1,500° C, the discharge of NOx will be reduced to nearly zero. The possibility of realizing such a combustion is called "catalyst combustion."

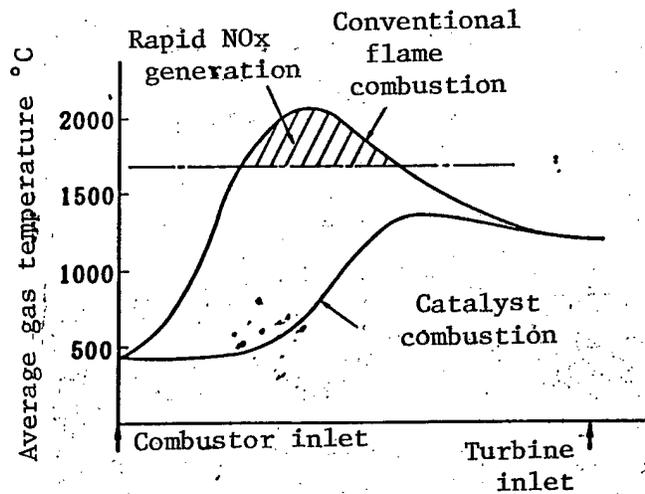


Figure 1. Comparison of Gas Temperature History Between Conventional Combustion Method and Catalyst Combustion

Figure 2 shows the conceptual diagram of a catalyst combustor. The gas fuel is mixed with combustion air, passes through the ceramic-made honeycomb (Figure 3) [omitted] carrying catalytic ingredients such as platinum and palladium, reacts to them, and generates a high-temperature gas. The catalyst combustor can be said to be an ideal form of the gas turbine combustor, but before it is put to practical use, many problems must be solved. Needless to say, the development of highly active catalysts at low temperatures and highly heat-resistant catalysts at high temperatures is necessary. On the other hand, research on its utilization technologies to ease those requirements is considered to be indispensable to putting this combustor to practical use.

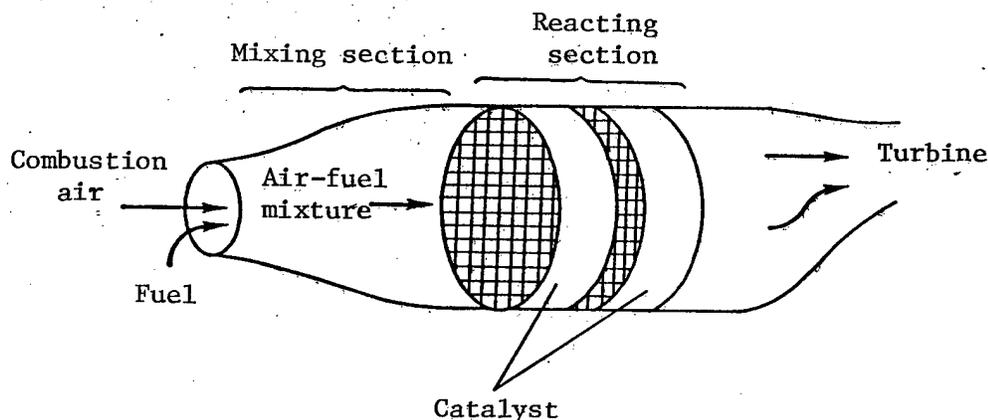


Figure 2. Conceptual Diagram of Catalyst Combustor for Gas Turbine

The author and others started basic research on catalyst combustion about 5 years ago and have conducted to date experiments on the reaction characteristics of catalysts under the atmospheric pressure and also atmospheric pressure experiments of preburner system catalyst combustor. As a result, it has been proven that the NO_x concentration in the exhaust is more than two digits lower than in the flame combustion at 0.1 ppm or below and that a specific combustion intensity of the same level as the industrial gas turbine combustor can be obtained.

From this fiscal year (fiscal 1986), "research on gas turbine low-pollution catalyst combustion" using the test and research expenditures for national environmental pollution prevention, etc., has started. Here in this research, it is planned to conduct experiments on the reactivity of catalysts under high-pressure conditions equal to those for the actual gas turbine combustor, exhaust gas evaluation tests of catalyst combustor in the range up to about 30 kg/cm² and, at the same time, research on technologies indispensable to the design of the catalyst combustor, such as fuel-air mixing technology.

20150/8309
CSO: 4306/2471

GOOD PERFORMANCE OF LE-7 LIQUID OXYGEN TURBOPUMP CONFIRMED

Tokyo KOGIKEN NYUSU in Japanese Aug 86 pp 5-6

[Article by Kenjiro Kamijo, Tsunoda Branch Office]

[Text] The Tsunoda Branch Office of this laboratory is pushing the test-manufacture and research on a liquid oxygen turbopump for the first-stage main engine (LE-7) of the H-II rocket. The design of this turbopump has already been introduced in KOGIKEN NYUSU (No 319).

The main part of this turbopump comprises the inducer to suck in a large amount of liquid oxygen (0.4 MPa, 229 kg/s) at a relatively low pressure, the main pump to send high-pressure liquid oxygen (21.3 MPa, 203.5 kg/s) to the main combustor, the split pump to feed further high-pressure liquid oxygen (32.7 MPa, 25.6 kg/s) to the preburner, and the gas turbine to drive these pumps. The gas turbine of about 9,000 horsepower is driven by the high-pressure high-temperature hydrogen excessive-concentration gas (23.7 MPa, 971 K, 16.0 kg/s) generated in the preburner. Besides, as the important parts, there are the self-lubricating bearings which are cooled by the pump fluid (liquid oxygen) and yet support the high-load high-speed revolution, and the shaft sealing to separate liquid oxygen of the pump section and turbine-driving gas, and on these parts independent tests are also being made.

In Figure 1 [omitted] a composite picture of the first-phase prototype liquid oxygen turbopump has been shown. In designing this turbopump, since importance has been attached to the simplicity of its structure, the arrangement of the rotating parts in particular has been very simplified in comparison with the high-pressure liquid oxygen turbopump of the space shuttle main engine (SSME).

The first-phase prototype liquid oxygen turbopump (Type 2) and its test equipment were completed toward the end of fiscal 1985, and thus its test was started. Up to now, cold running tests using liquid nitrogen for the pump fluid and cold hydrogen gas for the turbine driving gas have been conducted, with the result that the design number of revolutions (20,000 rpm) has been attained and the fluid performance and the quality of structural design have become considerably clear. A part of this result is introduced below.

The general performance acquired in connection with the main pump has been shown in Figure 3. As for the pump, the law of similarity is applicable, and therefore, for the flow ratio (Q/Q_d) of the horizontal shaft, $Q/Q_d = 1$ becomes the design point regardless of the number of revolutions. The pressure coefficients (ψ_m, ψ_i) of the vertical shafts are what have been acquired by dividing their respective heads (pressure buildup/fluid specific weight) by twice the head of peripheral speed of the centrifugal impeller tip (U_t^2/g , U_t : peripheral speed, g : gravitational acceleration). To begin with the efficiency, a higher value of about 7 percent than the required value (design value) has been obtained regardless of the number of revolutions. It is conceivable that the flow force design of the large-flow high-pressure impeller has been proper on the whole. As a matter of course, that the precision-casting heat-resistant alloy three-dimensional centrifugal impeller has been completed at a high accuracy can also be cited as another factor that has led to the acquisition of this high efficiency. Next, as for the pressure buildup of the main pump, both the inducer and the main pump have exceeded the required value. However, there is no need to change the design, and it becomes possible to match it with the LE-7 engine by making some change in the working number of revolutions.

The liquid oxygen turbopump has the potential of ignition and explosion. In order to make this danger smaller, it is necessary to conduct many tests hereafter on such matters as restriction of shaft vibration, adjustment of axial thrust, and bearing sealing performance. The number of tests conducted this time has not been very large, but relatively satisfactory results have been acquired as to the aspect of the above-mentioned structure.

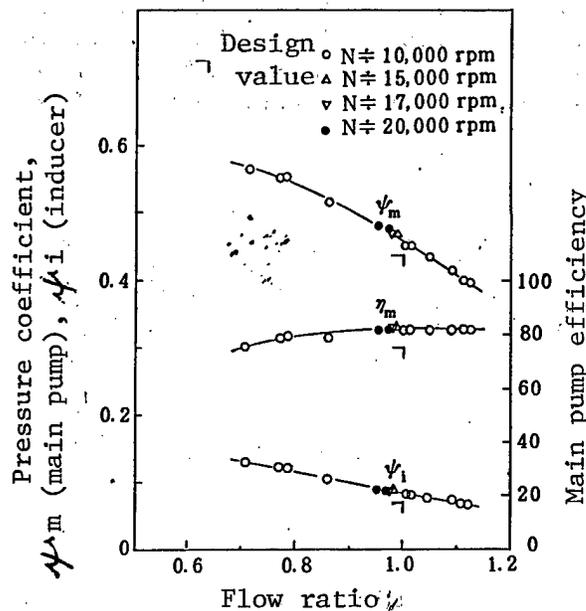


Figure 3. General Performance of Main Pump

An example of the result of shaft vibration of the rotating system of the first-phase prototype liquid oxygen turbopump is shown in Figure 4. The diagram shows the analysis results of the vibration of the main impeller tip section when operated roughly at the design number of revolutions. With the vibration corresponding to the rotational frequency (rotation synchronous) showing a considerably small value of about 10 microns, the rotating system has been very stable. Furthermore, there has been almost no vibration of the frequency lower than the rotation synchronism. In the development of the SSME high-pressure liquid oxygen turbopump, it appears that the rotation asynchronous shaft vibration was a great problem and besides, it poses a problem also for the increase of power of the SSME. That priority has been given to the simplicity of the rotating system as shown in Figure 1 is believed to have led to this satisfactory result.

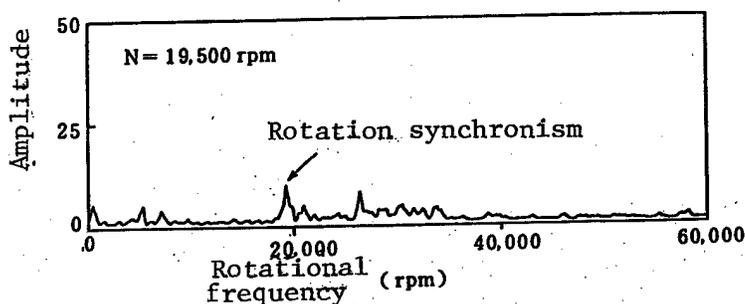


Figure 4. Vibration of Main Pump Impeller Tip

As has been mentioned above, the first-round test of the first-phase prototype liquid oxygen turbopump has advanced relatively smoothly. However, since several points that should be improved have been found in both the sample machine and the test equipment, measures have been taken to amend these, thereby conducting the second-round test from early July of this year.

20150/8309

CSO: 4306/2471

CASCADE FLOW ANALYSIS BY NAVIER-STOKES EQUATION

Tokyo KOGIKEN NYUSU in Japanese Aug 86 pp 7-10

[Article by Osamu Nozaki, Aircraft Propulsion System Aerodynamic Simulation Group]

[Text] As the performance of the large electronic computer has improved, numerical simulation of the flow around the blade of the aircraft, for instance, is being conducted actively. In the compressor and turbine cascades of aircraft engine, multiple blades are put side by side closely, and the pressure gradient in the flow direction is large. Thus they have more complicated properties than the independent blade. At present, therefore, it is the mainstream to use potential, Euler's equation, etc., as the basic equation but, for knowing the phenomenon caused by the viscosity like the interference of shock waves and boundary layers, it is necessary to solve the Navier-Stokes (N-S) equation.

The Aircraft Propulsion System Aerodynamics Simulation Group has developed a two-dimensional cascade analysis program by the N-S equation by expanding the two-dimensional high Reynolds number transonic profile analysis code NSFOIL and the lattice formation program AFMESH for the independent blade, which were already developed by Kawai and Hirose of the Aerodynamics 2d Division, so as to fit the cascade flow.

The computation lattice is shown in Figure 1. Shown in Figure 1 (a) is the turbine cascade, and shown in Figure 1 (b) is the compressor cascade. Measures have been taken to have the outside boundary follow the directions of inflow and outflow, to space the lattice strips finely, and further to have them cross at right angles on the boundary. The results of computation conducted by respective lattices are shown below. In either case, the Reynolds number in the upstream is 1×10^6 . Figure 2 shows the computation results of the turbine blade. Shown in Figure 2 (1) is the static-pressure distribution of the blade surface, which agrees well with the simultaneously shown result of the cascade experiment (NAL TM-451) by Minoda, et al. of the Motor Division. Shown in Figure 2 (2) is the density distribution between the blades, which is expressed so that the density becomes higher in the order of blue, green, and red. It shows the state of the density gradually dropping in passage through the cascade.

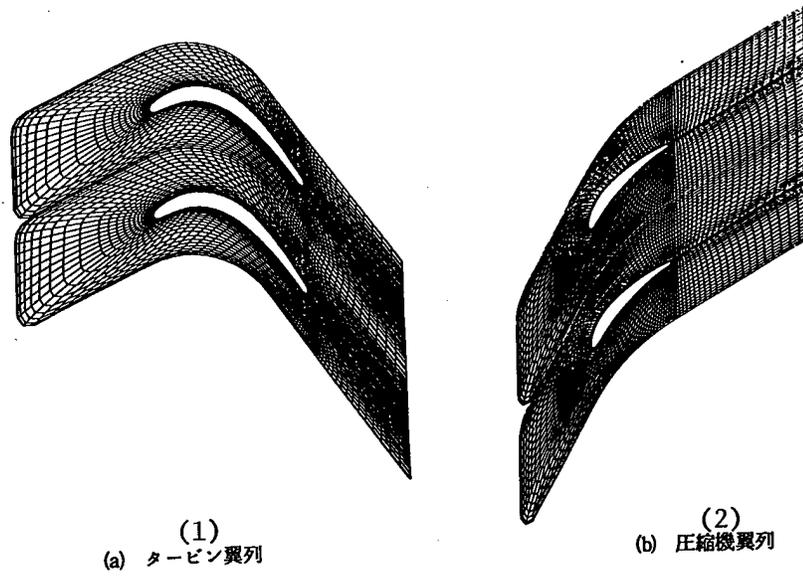


Figure 1. Computation Lattice

Key:

1. (a) Turbine cascade
2. (b) Compressor cascade

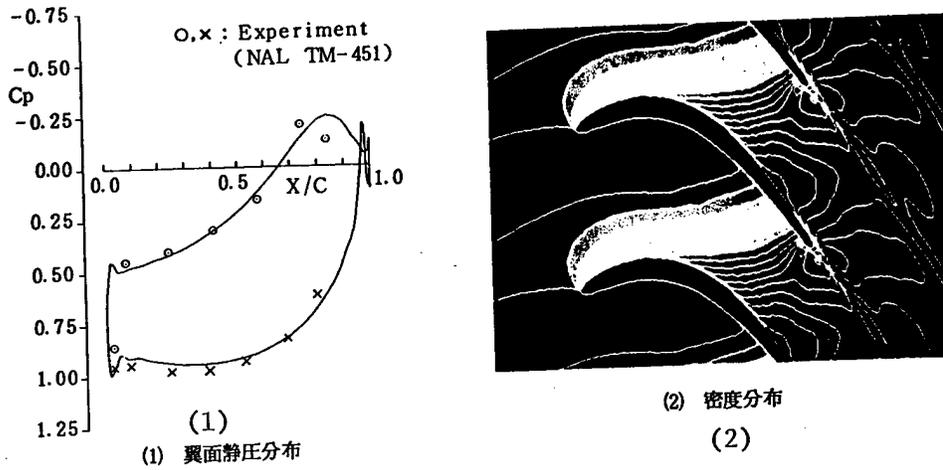


Figure 2. Computation Result of Turbine Cascade

Key:

1. (1) Blade surface static-pressure distribution
2. (2) Density distribution

The same computation can be made also in the compressor blade. Separation is more easily caused than in the turbine blade, and in the process of computation, the static pressure, etc., sometimes continue to vibrate, but in such a case, through a series of density distributions (Figure 3) [omitted] in one cycle of vibration, it is possible to know the state of the vortex, which is caused by the separation that occurred in the back side of the blade, flowing to the downstream and reattaching.

Like this, for the cascade wherein the pressure gradient exists in the flow direction, numerical computation by the N-S equation has become possible, and its results have been relatively agreeable with the experiment results. Hereafter, it is planned to verify still more computation results by experiments and, at the same time, to improve it so as to become capable of handling even the cooling problem of the turbine blade and to expand it further to the three-dimensional flow.

20150/8309

CSO: 4306/2471

PAYLOAD BOOMERANG TECHNOLOGY DESCRIBED

Tokyo KOGIKEN NYUSU in Japanese Sep 86 pp 1-2

[Article by Akira Onchi]

[Text] Payload boomerang technology means that after an experimental PS (payload satellite) is launched from the SS (space station) into space and experiments are performed while flying the experimental PS in space, the experimental PS will be recovered by the SS. Such an experimental PS can be regarded as a kind of free flier, and compared with free fliers which are usually considered, it is possible readily and inexpensively to perform repeated experiments by using such an experimental PS. It is necessary to collect basic data on space experiments, and it can be considered that this payload boomerang technology is extremely useful because experiments can be performed readily and repeatedly.

The PS which has been assumed up to now has a mass of 500 kg, a flight time of several hours or 10-odd hours, and a relative speed of less than 100 cm per second against the SS. A gravity environment of 10^{-6} gravity or 10^{-7} gravity will be realized. Also as mentioned later on, the PS will correct its orbit by opening an aerodynamic parachute and changing the aerodynamic resistance during flight. Figure 1 shows an imaginary picture of PSs, which will land and take off from the top of a DTB (deployable truss beam) which will be installed on the module of the SS.

The payload boomerang technology is characterized by the fact that the orbit of PSs is controlled by positively using aerodynamics in a rarefied atmosphere at an altitude of 400 to 500 km. The movement of the PS and SS will be mentioned in the item "dynamics" including aerodynamics. Inoue, an engineer with the First Aerodynamics Division, has calculated the perturbation on the assumption that the orbit is close to a circle, and has made a program and an equation for indicating the orbit, which can be put to practical use. Figure 2 is an example of the above calculation and shows the relation between the polar coordinates R and ϕ Phi of the orbit. All land and take-off places are located 30 meters below the center of gravity of the SS. The circular mark means the orbit in which a PS opens a parachute at 3,800 seconds after it is launched from the SS, and after 7,600 seconds, it will return to the SS. The launch speed is 11.7 cm per second. The return orbit and launch speed are related to the altitude of the SS, solar direction, shape (aerodynamic

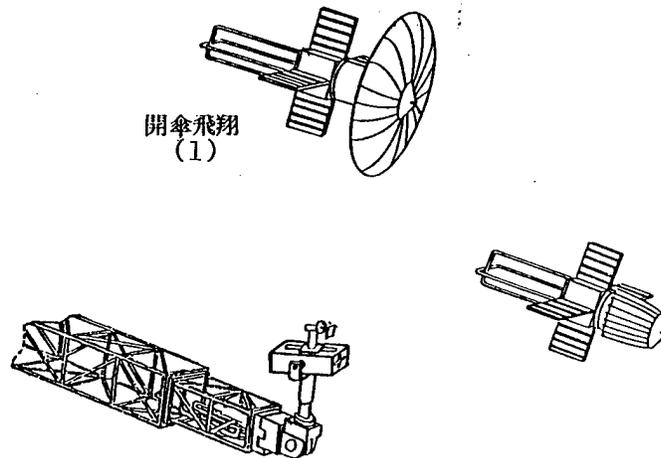


Figure 1. Graphic Representation of Boomerang Satellite

Key:

1. Parachute opening in flight

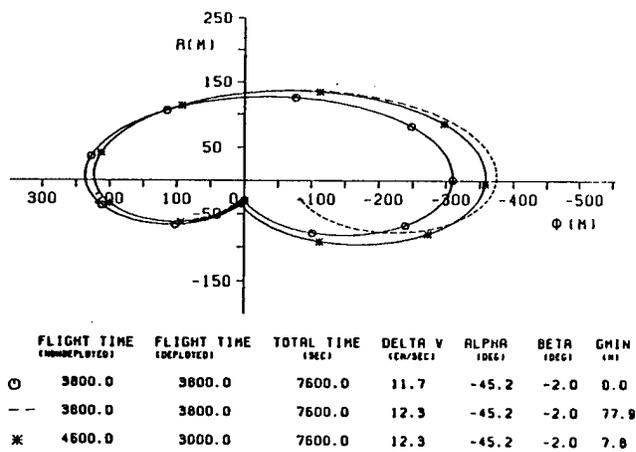


Figure 2. Relative Orbit of Boomerang Satellite

resistance) of the PS, etc. When the value of these items is different from that of the items during the actual flight of the PS, the PS may deviate from its orbit and may not be able to return to the SS. For example, when the value of the launch speed is different from that of the actual one by 5 percent and is 12.3 cm per second, as shown in dotted lines in Figure 2, the orbit will deviate 80 meters from its return position. In such a case, the deviated orbit can be corrected to its original return orbit by changing the time for opening a parachute. The asterisk shown in Figure 2 is an example of the corrected orbit. It can be appreciated that when the time for opening a parachute is determined at 4,600 seconds after a PS is launched, the PS will return to a place close to its landing and take-off place. In the case of actual flight, the initial orbit of the PS will be chased, the time for opening a parachute will be calculated on the basis of data obtained from this chase, and this time will be corrected in accordance with instructions given from the outside (for example, the SS). As mentioned up to now, the correction of the orbit of the PS is carried out by controlling the time for opening a parachute. This correction work does not need any active control according to the jet.

The main processes in the use of the payload boomerang technology are the launching of a PSS from the SS, flight (experiment), opening of a parachute, and recovery of the PSS to the SS. A unit for launching PSs must have the very small error of the launching speed. Also, the PS must be constructed so that it can smoothly open a parachute in accordance with instructions given from the outside. It is necessary to make the unit and PS on an experimental basis and to conduct preliminary tests for them, because they will be operated in a weightless environment. The method of throwing a net and direct acquisition according to a manipulator can be considered as methods of recovering the PS. Also, it is desirable to design a PS so that the restoring force of both aerodynamic torque and gravitational inclination torque can act on the PS, because the attitude stability must be ensured in the PS during flight. The above topics are presently being studied.

It is not long since research on the payload boomerang technology was started and there are many problems which should be solved from now on, but preliminary experiments will be performed by using a space shuttle at a stage in which research is promoted to some extent. This is because it is considered that these preliminary experiments are effective for the future PS.

20,143/9599
CSO: 4306/2534

NUMERICAL SIMULATION OF TRANSONIC FLOW AROUND 'ASUKA'

Tokyo KOGIKEN NYUSU in Japanese Sep 86 p 2

[Article by Susumu Takanashi]

[Text] NAL (National Aerospace Laboratory) is conducting research on the numerical simulation of transonic flow around a low-noise STOL (short take-off and landing) experimental aircraft, "Asuka." The purposes of this research are to evaluate the high-speed aerodynamic characteristics of the Asuka, to evaluate the aerodynamic interference between the elements and airframe according to the parametric study, and to construct a numeric data base.

In recent numerical simulations, importance has been attached to the consideration of the actual flow area conditions and a realistic airframe shape. First NAL will consider the combination of a wing and engine nacelles, and, second, it will consider the complete airframe shape including tail units in this research. Also, with regard to equations which should be solved, NAL is scheduled first to consider the Euler equation and second to consider the Navier-Stokes equation with a view to rightly evaluating the non-linear effect in transonic areas.

In order to evaluate rightly the aerodynamic interference, etc., the airframe shape of the Asuka must be expressed as precisely as possible, because elements of the airframe are close to each other. A multi-block type coordinate-producing code has been used to evaluate rightly the aerodynamic interference, etc. This code was developed with a view to directly handling the airframe with a complex and three-dimensional shape. According to this method, the airframe shape is considered in a number of blocks, and these blocks are mapped into rectangles in the calculation space. It is readily possible to map such blocks into such rectangles as long as the airframe shape can be considered in blocks, even if it is extremely complex. Also, a windward finite differential method is used in a secondary accuracy-finite volumetric method. A code according to the secondary accuracy-finite volumetric method has been developed with a view to analyzing flow areas. In this research, the numerical simulation of the transonic flow around the Asuka will be carried out by combining both codes.

The photograph [omitted] shows an example of the results of analyzing the transonic flow around the combination of a wing and engine nacelles. With

regard to the conditions for calculating the transonic flow, the upstream Mach number is 0.7, the attack angle is 2 degrees, and an experimental value obtained from the TPS (turbine-powered simulator) simplex tests is given to the boundary between the inlet and outlet of the engine nacelles. Contour lines shown in the photograph mean isobars drawn on the surface of the wing and engine nacelles. The color of these isobars is selected in order of wavelength so that the color of a point in which the pressure is high is red and that of points turns to blue in proportion to the lower pressure. But low-pressure areas just before shock waves are emphasized by applying white to the space between light blue and blue. Also, the example shown in the photograph shows the distribution of contour lines in the central and vertical cross section of the outside of the engine nacelles.

The flow area is characterized by the existence of strong shock waves caused by channel flow generated between two engine nacelles or the existence of shock waves, etc., which occur in the vicinity of the leading edge of the outer wing. Also, the flow of engine exhaust gas which is repeatedly expanded and compressed can be seen in the photograph. It can be said that the calculation result clearly shows the characteristic of standing flow areas.

At present, NAL is analyzing the complete airframe shape as a next step by using the Euler equation. Simultaneously, NAL is scheduled to make a comparison with the result of high-speed wind tunnel tests for the Asuka performed in a transonic wind tunnel of NAL. This comparison is indispensable for clarifying the quantitative correspondence with experimental values as well as inspecting the analyzing code.

It took about 20 hours for the M380 in the Calculation Center to calculate the combination of a wing and engine nacelles. However, it will take only about 40 minutes for a vector computer which will be introduced with an NS (numerical simulator) to calculate this combination, and it will take only about 3 hours for this computer to calculate even the complete airframe shape. In addition, there is still sufficient room for shortening the calculation time in the calculation code itself. It seems that the calculation code can sufficiently be used for wide parametric studies in the future.

Also, the calculation code used in this research has been developed as a part of the joint research on calculation aerodynamics, which has been conducted by NAL and KHI (Kawasaki Heavy Industries, Ltd.) since fiscal 1985.

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NEW TRIAL OF VIBRATION TESTING METHOD

Tokyo KOGIKEN NYUSU in Japanese Sep 86 pp 3-4

[Article by Tetsuhiko Ueda]

[Text] This article will discuss a trial of a vibration testing method which will be used in the time domain. The vibration test is indispensable for obtaining dynamically elastic characteristics of the structure. In particular, it is necessary to anticipate the flutter phenomenon which will cause structural destruction on the wings of aircraft, fins of rockets, turbine blades of engines, etc. Therefore, the identification of structural characteristics according to vibration tests plays an important role in this anticipation. The sine dwell method and transfer function method can be cited as methods being used widely and presently in such vibration tests. Definitely speaking, the sine dwell method is used to search for resonance points, and the transfer function method is used to process data mathematically in the frequency domain by using an FFT (fast Fourier transformation) analyzer, etc. Simple and highly accurate measuring systems have come into the world, because in recent years, the latter method has rapidly progressed in both the software and the hardware fields. However, it is necessary to use these methods properly with consideration for the characteristics of objects, because the methods have both merits and demerits. The VATREM (vibration analysis in the time domain by the real eigenvalue method) which will be introduced hereunder is a new trial different from both of the above methods and can be regarded as a kind of time domain method.

The time domain method means that modal parameters are directly identified without any conversion of response time history into the frequency domain. The purpose of an instrumentation program prepared by NAL is to establish a practical testing method on the assumption that this program can be processed with personal computers. Briefly mentioning the data processing method, first characteristic matrixes of the system are expressed from the free vibration response by using a matrix logarithmic function, and a real eigenvalue corresponding to the natural frequency is found with some of the characteristic matrixes. An adaptive digital filter is automatically designed by using this real eigenvalue, and specific frequency components are extracted by applying them to the original time history. The natural frequency and damping factor can be found accurately by applying an impulse invariant method

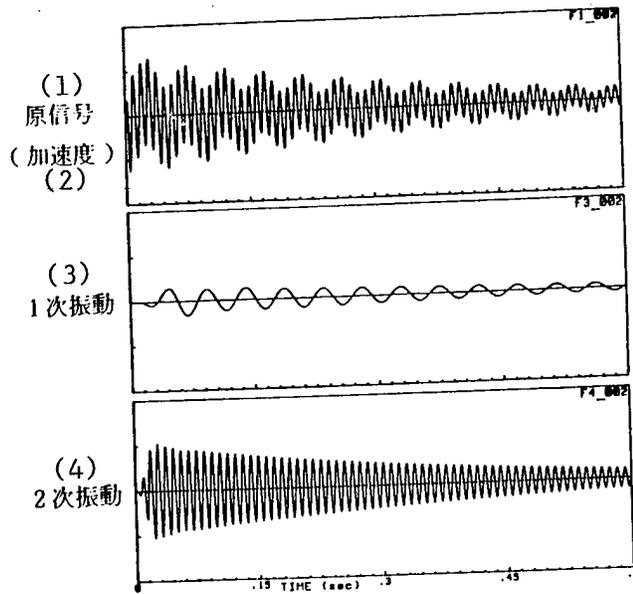


Figure 1. Processing Example of Adaptive Digital Filter

Key:

1. Raw signal
2. (Acceleration)
3. Primary vibration
4. Secondary vibration

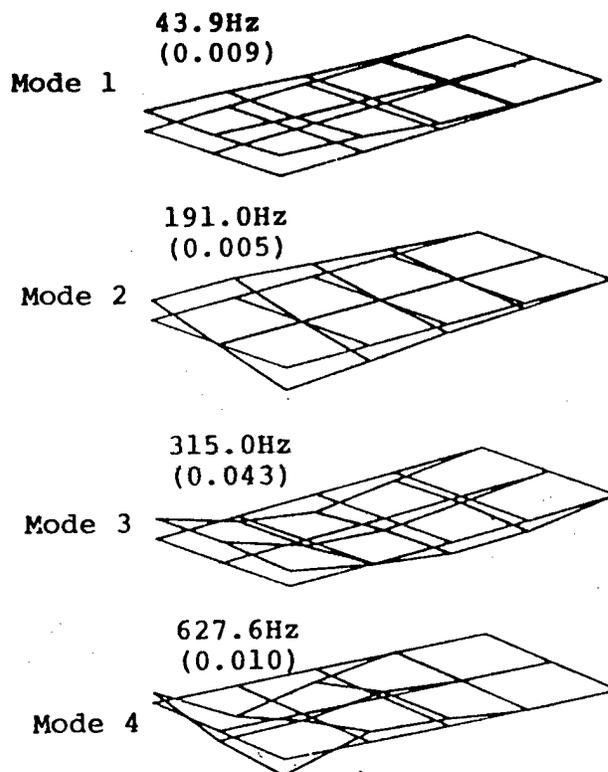


Figure 3. Examples of Processing Result According to VATREM
(The figure in parentheses shows damping coefficient.)

used in the Z conversion (discrete Laplace transformation) to the result obtained from the above extraction. The vibration mode is animated on a graphic display by making it correspond to each found natural frequency and by composing the entire mode shape from a simultaneous data group at a number of measuring points. Figure 1 shows an applicable example of an adaptive digital filter. As may be seen from the applicable example, the adaptive digital filter sufficiently separates the frequency components from each other. Figure 2 [omitted] shows the units for the VATREM, and Figure 3 shows examples of the result of processing modes according to the VATREM, respectively.

It can be said that the most important features of this method are the simplification of units and the short measuring time. The main composing units are the response detector and personal computer (PS 9816 is used for the method). Also, this method does not need any specific vibrator for exciting free vibrations. Vibration is generated by applying an impact with a wooden hammer to cantilever plates shown, as shown in Figure 3. According to instrumentation response data obtained from these examples by using five accelerometers, the acceleration output for 0.12 second is 3-class. Therefore, these data indicate that it is possible to analyze sufficiently the vibration with a time history in an extremely short time. Also, this instrumentation program consists of modules in which BASIC (beginner's all-purpose symbolic instruction code) languages are used, and conversational modes are positively taken in the flow.

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CAD WIND TUNNEL TEST FOR HALF-CUT MODEL OF 'ASUKA'

Tokyo KOGIKEN NYUSU in Japanese Sep 86 pp 5-6

[Article by V/STOL Aircraft Research Groups 3, 11]

[Text] A low-noise STOL experimental aircraft, "Asuka," being researched and developed by NAL is presently at a full-scale flight experimental stage.

The main wing itself of the C-1 transport, which is a mother aircraft of the Asuka, has not been changed because the main purpose of research and development on the Asuka was to establish a USB (upper-surface blowing) which will realize a revolutionary STOL performance. The V/STOL (vertical short take-off and landing) Aircraft Research Group Nos 3 and 11 have been conducting research on the possibility of a rise in aerodynamic performance of the optimum shape of main wings as part of the research on the practical use of future STOL aircraft. Tests were conducted in the above research by using a half-cut model with a main wing shape designed with a CAD (computer-aided design) system and are called "Low-Speed Wind Tunnel Test."

A super-critical airfoil has been adopted in an 8 percent model of the main wing obtained by using the CAD system with consideration for high-speed performance. A short nozzle was adopted in engine exhaust outlets with a view to lightening the model as much as possible. The above groups aimed at obtaining sufficient high-lift characteristics without any leading-edge BLC (boundary layer control) in the low-speed wind tunnel test.

The half-cut model has been made by combining this main wing and a fuselage of a conventional STOL experimental half-cut model (Asuka model) and is called a "CAD Model." The photograph [omitted] shows a CAD model installed in a wind tunnel. Figure 1 shows the main data on the main wing, an outline drawing of the CAD model, and that of the Asuka model.

As an example of results, Figure 2 shows the lift characteristics of the CAD model with no leading-edge BLC, those of the Asuka model with no leading-edge BLC, those of the CAD model with a leading-edge BLC, and those of the Asuka model with a leading-edge BLC. The comparison between both models cannot be made strictly because they are slightly different from each other with respect to the flapping angle of both model shapes, but it has been clarified that the CAD model even with no leading-edge BLC has lift characteristics which are

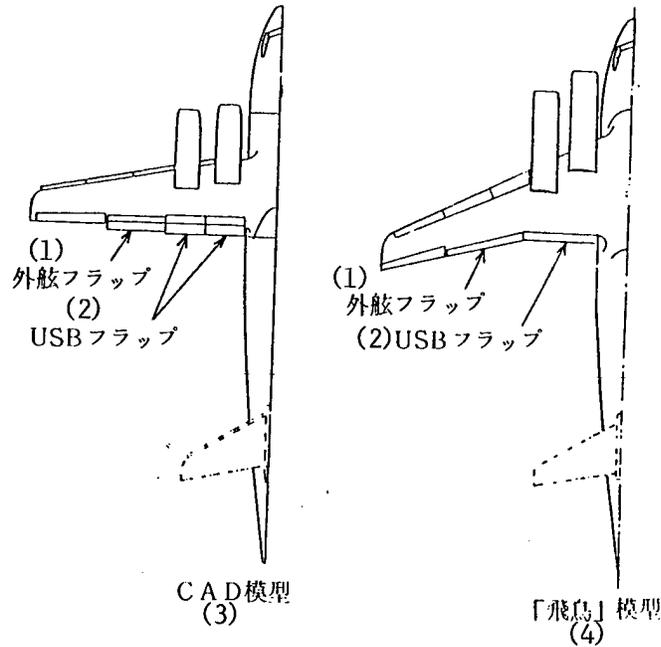


Figure 1. Comparison of Main Data on Main Wing

Key:

1. Outside chord flap
2. USB flap
3. CAD model
4. Asuka model

	CAD Model	Asuka Model
Area (one of the wings, square meter)	0.2997	0.3856
Wing span (one of the wings, meter)	1.224	1.224
Aspect ratio	10.0	7.8
Average aerodynamic wing chord length (meter)	0.2637	0.3547
Sweep back angle (degree)	8.2	20
Taper ratio	0.35	0.32
Wing thickness ratio (percent)	15 (Wing root) and 12 (average)	12 (Wing root) and 11 (wing tip)
USB flap	Double flap	Double flap
Outside chord flap	Double-slotted flap	Quadruplex-slotted flap

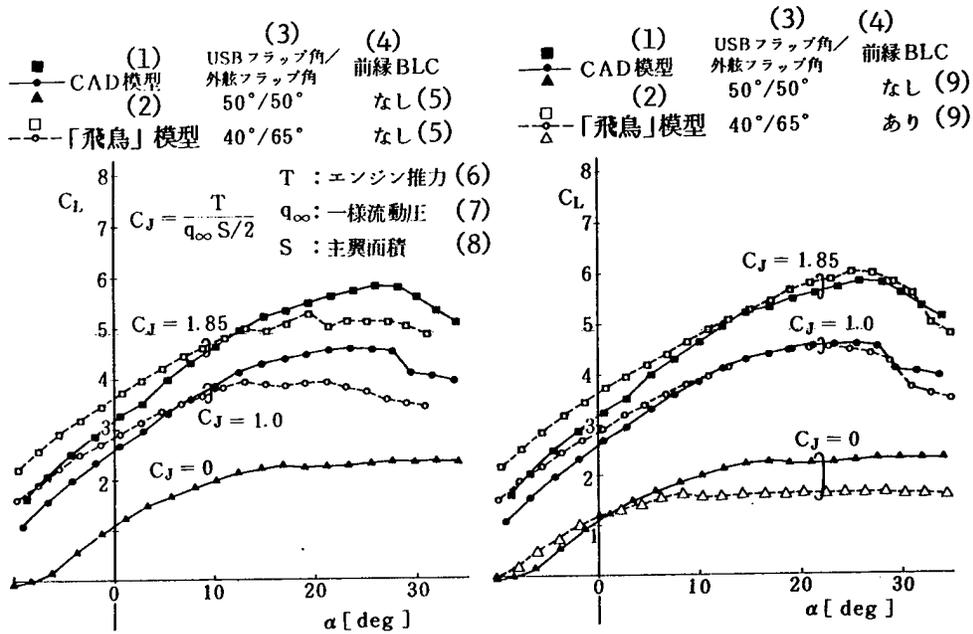


Figure 2. C_L Curve (Landing Form, with a Vortex Generator)

Key:

1. CAD model
2. Asuka model
3. USB flap angle/outside chord flap angle
4. Leading Edge BLC
5. Nil
6. T:Engine thrust
7. q_∞ :Homogeneous-flow dynamic pressure
8. S:Area of main wing
9. Existence

almost the same as those of the Asuka model with a leading-edge BLC. That is, if the wing's flat shape is optimized, aircraft will be able to have sufficient lift characteristics even if these aircraft have no leading-edge BLC. Therefore, it will be unnecessary to use any leading-edge BLC in aircraft, and piping systems used in the BLC can be lightened. In addition, the engine thrust can be used effectively, because it will be unnecessary for engines used in the BLC to exhaust any gas. Also, it is expected that engine nacelles can be lightened by adopting such short nozzles in actual aircraft, because a sufficient Coanda effect can be obtained from short nozzles used in the CAD model.

The result of the above low-speed wind tunnel test for the half-cut model shows that the sharp increase in aerodynamic performance and decrease in the cost and weight of aircraft can be expected. Therefore, it can be expected that there is a strong possibility of STOL aircraft according to the USB system being put to practical use in the future.

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TEST FOR LOW-SPEED FLUTTER OF ATP BLADE

Tokyo KOGIKEN NYUSU in Japanese Sep 86 pp 6-7

[Article by Masataka Hashidate]

[Text] The ATP (advanced turboprop) is an energy conservation technology whereby propeller-driven aircraft can fly at a propulsion efficiency of about 80 percent up to a high speed of Mach 0.8. But new research on structural and aerodynamic characteristics which cannot be seen in the wings of conventional propeller-driven airplanes must be conducted, because airfoils characterized by the thin wing, low-aspect ratio, large twist angle, and large sweep-back angle are used in this technology. There is a strong possibility of flutter being generated on particularly thin wings with the large aerodynamic load, and the problem of flutter generated on wings is one of the important subjects which must be solved with a view to establishing the ATP.

NAL has no experience in conducting flutter tests for rotary wings including the ATP. Then tests were conducted while emphasizing the following two items for the purpose of establishing a method of conducting tests for rotary wings in a wind tunnel: 1) Establishment of technology for manufacturing rotary wing flutter model, and 2) extraction of problematical points of rotary wing flutter wind tunnel tests. Originally, the ATP blade has the large twist angle and large sweep-back angle, but the above tests are preliminary. Therefore, it was decided that a wing with neither twist angle nor sweep-back angle would be manufactured with a view to readily making a comparison with theories.

It was decided that a wing model would be constructed so that an aluminum material with a width of 50 mm, a thickness of 1.7 mm, and a length of 800 mm is used as a core metal, and four blade elements and another four blade elements are installed on the core metal. The former four blade elements have an airfoil NACA (National Advisory Committee for Aeronautics)-64A010 and a wing span of 300 mm, and the wing span of the latter four blade elements is reduced in proportion to close to wing root. These blade elements are made of balsa material, and sheets of Japanese paper are attached to their skins. Also, they are constructed in the shape of a box so that the weight per blade element is less than 24 grams. Each blade element was fixed on the core metal with two machine screws having a diameter of 3 mm. It was confirmed that such blade elements were able to withstand the static load of up to 117.6 N

(equivalent to a centrifugal force of 600 revolutions per minute) in a centrifugal direction.

Prior to conducting wind tunnel tests, as a result of conducting vibration tests for wings, the primary frequency in the bending direction was 1.56 hertz, and that in the twisting direction was 9.15 hertz.

A pitch control unit with a capacity of 1 kW used in research on a windmill was modeled into an oil hydraulic motor-driven control unit, and this remodeled unit was used as a rotary testing unit. A large low-speed wind tunnel was used as a wind tunnel, and protective nets were laid anew on the windows of the wind tunnel measuring sections as a safety measure in the case where wings are damaged and their fragments are scattered in the large low-speed wind tunnel.

Before conducting tests for rotary wings, one of the rotary wings was fixed on the floor on the wind tunnel, and flutter tests for the rotary wing were conducted. (Refer to Photograph 1 [omitted].) Flutter was generated, when the homogeneous flow wind speed was 19.0 meters per second, and the frequency at that time was 7.5 hertz.

Next, two flutter wings were installed on a rotary unit. This object composed a relatively large rotor with a rotating diameter of 2.0 meters. The rotation speed and wind speed were increased gradually. It was observed that depending on the peripheral velocity ratio and pitch angle, the wing acted as a windmill or a propeller, and the wind tip moved in the backward or forward direction from the rotary face of a hub. Photograph 2 [omitted] shows the wing rotating as a propeller.

When the homogeneous flow wind speed was 16 meters per second and the rotation speed was 186 revolutions per minute in the tests for rotary wings, the wing root was deformed (mainly bent), because of aerodynamic elasticity, and these tests were finished. The deformed wing root is shown in Photograph 3 [omitted]. Thanks to the success of the above tests, NAL was able to gain valuable experience in the method of manufacturing the rotary wing flutter model and that of conducting wind tunnel tests, and was able to attain its purpose. At present, NAL is carrying out the data analyzing work and is conducting the comparison and study of theoretical calculations.

In the future, NAL is scheduled to manufacture a full-scale flutter model of an ATP blade and to perform tests for clarifying the flutter phenomenon.

Finally, I want to say that the above tests were conducted in cooperation from the Second Aerodynamics Division, First Airframe Division, Aircraft Noise and Emission Research Group, and Administration Division Machining Section.

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BRIEFS

MAGNETIC BEARING FLYWHEEL EXPERIMENT--The magnetic bearing flywheel experiment equipment (KOGIKEN NYUSU No 324) developed by the National Aerospace Laboratory was launched by the H-I rocket (two-stage type) test vehicle No 1 from the Tanegashima Space Center at 0545 hours on 13 August 1986. After entry into orbit, the launch lock mechanism fastening the flywheel was released and the magnetic levitation of this flywheel was confirmed. The H-I rocket, which succeeded in its first flight, is that on which this laboratory, jointly with the National Space Development Agency, conducted tests and research, such as the airframe vibration test and the transonic/supersonic wind-tunnel test, as well as the development of its LE-5 engine liquid oxygen turbopump prototype model. [Text] [Tokyo KOGIKEN NYUSU in Japanese Aug 86 p 10] 20150/8309

CSO: 4306/2471

SDI-RELATED INDUSTRIES REVIEWED

Tokyo TOSHI KEIZAI in Japanese February 87 pp 14-15

[Excerpts] 1-2 Trillion Dollar Ultra-Project

It has been about three months since the Japanese government decision to participate in the Strategic Defense Initiative (SDI) of the United States. U.S.-Japanese negotiations to pin down the conditions began at the end of October and positive action has begun to be shown toward participation by Japanese firms in SDI research.

SDI, which was highlighted at the U.S.-Soviet talks in Reykjavik that broke down a while back, is the strategic defense initiative was proclaimed by President Reagan in March 1983. It is the construction of a defense network that places laser satellites or particle beam satellites in space and destroys Soviet intercontinental ballistic missiles in four stages (directly after launch, before warhead separation, during ballistic flight, and at the end of the trajectory).

Currently, Great Britain, Israel, France, Canada, and West Germany are participating under government leadership or civilian leadership. Japan also approved participation at a 9 September cabinet meeting. The main form of Japanese participation will be private enterprise.

The schedule is divided into four stages from research to installation. The first stage is the research and development stage up to the early 1990's. The second stage is the full development stage beginning in the early 1990's. The third stage is partial installation beginning in the mid-1990's. The fourth stage is full installation by 2005. Moreover, the research project extends over a wide field such as super high-speed computers, ultra high sensitive sensors, and super high-output lasers. An investment of 26 billion dollars in research expenditures is planned for the five-year period from 1985 to 1989. Already 1.4 billion dollars has been allocated in the fiscal 1985 budget, and 2.75 billion dollars in fiscal 1986. Research has been commissioned to universities, research agencies and mainly U.S. space/defense-related businesses.

However, one to two trillion dollars is necessary for actual deployment. The project is a long-range plan aimed at pure military use in the 21st

century under government leadership, but in actuality it is an imposing high tech development operation. SDI technology is general technology applicable to civilian demands also and if technology transfer is accomplished, the merits are very great. Cabinet approval of participation also emphasized this.

Due to this, the Japanese approach to SDI has been aggressive. From September 1986 to March 1987, three government and civilian joint survey teams already have been dispatched. The third survey team separated into three groups and traveled around to various facilities nationwide from 31 March to 9 April 1987. The three groups were the target surveillance, acquisition, tracking, and kill assessment (SATKA) field, directed energy weapons (DEW) field, and kinetic energy weapons (KEW) field.

Central among these is SATKA. The main parts of this are a millimeter wave laser radar, laser communications, optical fiber communications, volume high-speed data processing, and a fifth generation computer aiming at artificial intelligence. There are some views that two-thirds of the SDI-related expenditures are invested for this SATKA.

Japanese Related Prime Mover Companies

The technology related to this SATKA is technology that currently is Japan's strongest point. There have been strong requests by the U.S. Department of Defense for technology cooperation. Also there is no guarantee for Japanese companies that they will maintain this comparative superiority in the future. By research participation in SDI, they will strive to upgrade related technology.

For example, when Defense Department personnel visited individual Japanese companies in May 1983, feelers were put out on the possibility of technical cooperation with regards to radiowave absorption ferrite and voice recognition devices (NEC), solid state imaging elements with infrared detection function (Mitsubishi Electric), copper carbide fibers (Hitachi), and production technology (Mitsubishi Heavy Industries).

However, government activity also has been lively. Since creation of a framework for research participation is necessary, a second negotiating team was dispatched in December following the first at the end of October. If progress is smooth, they are ready to sign an exchange of official documents between Secretary of Defense Weinberger and Foreign Minister Kuranari during the latter's visit to the United States scheduled in January 1987.

The first negotiating team already has informed the United States of their thoughts that 1) Japan should be able to use the results of research participation, 2) in preservation of secrets, Japan will make use of existing laws and not establish new laws, and 3) the agreement made between the United States and Japan will be publicly announced.

Reflecting these actions of the Japanese government, major U.S. companies such as LTV, Lockheed, McDonnell Douglas, Hughes, RCA, and Rockwell International in succession have proposed tie-ups in SDI research with Japanese firms.

Table 1. Correlation Between JDA/Companies and Technology of Interest to United States

	Milliwave/Microwave Gallium Arsenic Materials	Element Parts	System	Active Antenna	Satellite Broadcasting Reception Device	Optico-electric	Lasers	Optical Processing	Optical Data Disk	Visible Light Image Processing	Infrared Image Processing	Night Vision Device	LAN Parts	Optical Fiber Gyros	Display Device
JDA TRDI 1st Research Center							X			X	X	X			
JDA TRDI 3rd Research Center		X	X	X							X			X	
NEC		X	X		X		X	X		X	X			X	
Hitachi					X		X		X	X	X		X		
Fujitsu	X	X	X		X				X		X		X		X
Mitsubishi Electric		X	X	X	X		X			X	X	X	X		X
Toshiba		X	X		X		X	X	X	X	X		X		
Sharp		X			X		X		X						
Sumitomo Electric Ind.	X	X					X						X	X	
Matsushita Electric Ind.		X	X		X		X	X	X	X			X		

On the Japanese side, defense-related core manufacturers such as Mitsubishi Heavy Industries, Kawasaki Heavy Industries, Ishikawajima-Harima, Mitsubishi Electric, Toshiba, NEC, and Nissan Motor have been active behind the scenes. Since tie-ups of U.S. and European firms already are proceeding at a fast pace, an acceleration of positions taken by Japanese firms is necessary.

Tie-up Methods Elaborate

However, there are still many unclear points such as what form participation specifically will take. The SDI office of the U.S. Department of Defense will order the research work but, for example, will the method of participation be direct contracts, or tie-ups with U.S. firms and contracts under a joint name? The most realistic probably would be participation as a member of a subcontract team of a U.S. firm which already has been identified.

Table 2. Firms Participating in 3rd SDI Survey Team (21 companies)

Ishikawajima Harima NIT Electronics Technology Oki Electric Industry Kawasaki Heavy Industries Kobe Steel Sumitomo Heavy Industries Sumitomo Electric Industries Sony Daikin Industries Toshiba Toray Nissan Motor Japan Aviation Electronics Industry Japan Steel Nippon Electric Company Hitachi Fuji Heavy Industries Fujitsu Mitsui Engineering and Shipbuilding Mitsubishi Heavy Industries Mitsubishi Electric

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ISSUES ON HUMANENGINEERING IN FUTURE AERONAUTICAL SYSTEMS

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[Article by Yukiko Kakimoto, Aeromedical Laboratory, JASDF: "Human Engineering Problems in the Future Aeronautical Systems--High Intensity, Unforgiving Missions, Mission Stress, Protection and Performance Enhancement (Part 1)"]

[Text] This chapter consists of "Performance" and "Protective Countermeasures." In the first part, the "Performance," and in the second part, "Protective Countermeasures" will be described.

Performance

1. Performance of Crew, Monitoring and Performance Expansion

(1) Foreword

By 2000, aircraft will become characterized by two words: avionics and mission type. Although stress experienced in such flights is almost the same as that of the present, extremely lengthy flight missions, the chemical-biological electromagnetic environment, and also the nuclear environment will be newly added. Accordingly, pilots will be under both physiological stress regarding the maintenance-operation of the avionics package.

It is possible to monitor the pilot's performance and the decrease thereof during the mission from various parameters by freely using current physiological and psychological technology, and it is also possible to take measures when performance reaches a critical level. One of the methods used for this purpose is the PCC (personal characteristics) card system, a card for each individual pilot. The parameter for each pilot is input on the card, and the card is inserted in the aircraft before takeoff. Through this system, the condition of a pilot during flight is monitored by computers, and the decrease in performance is corrected. The kind of parameters that should be used in this system is the issue. Figures 1 and 2 show the progress schedule of the research up to 2000.

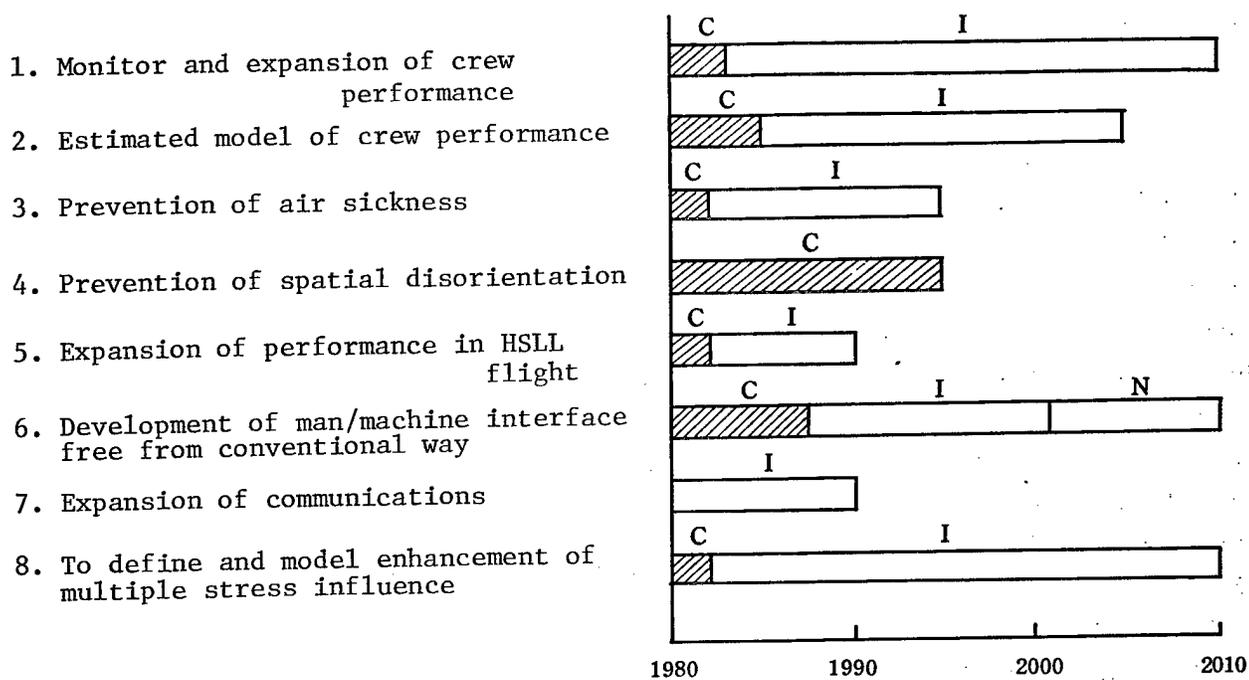


Figure 1. Research on Situations of Highly Intensified and Excessively Severe Mission Performance

C: Presently research in progress;
 I: Research requiring substantial efforts in the future;
 N: Research not even started yet.

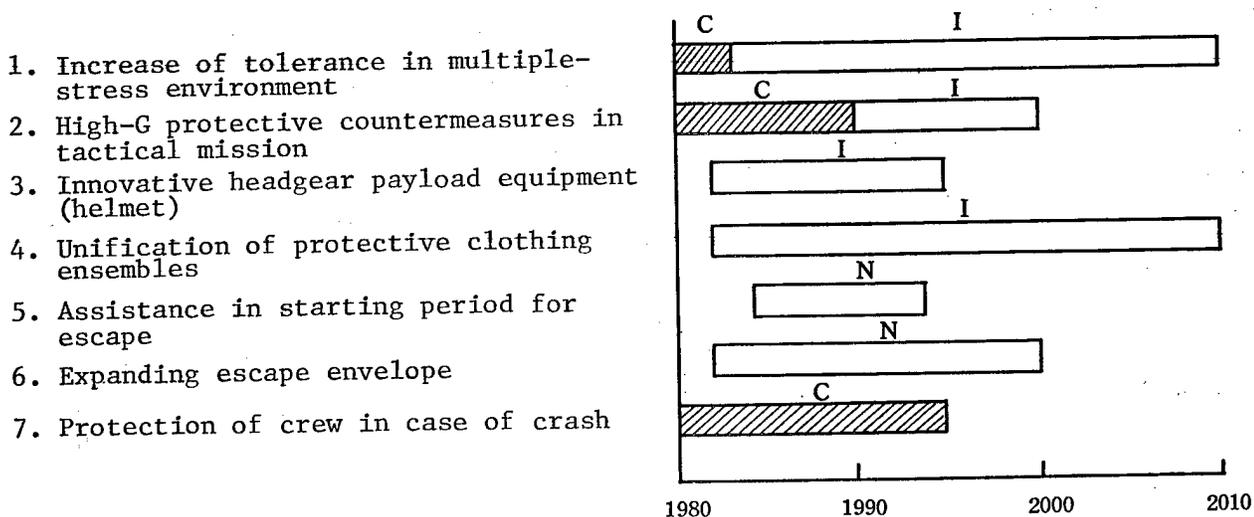


Figure 2. Research Situation on Protection Under Highly Intensified and Excessively Severe Missions

C: Presently research in progress;
 I: Research requiring substantial efforts in the future;
 N: Research not even started yet.

(2) Object

It is necessary to conduct research in the following four areas aimed at the development of methods to monitor pilot performance during flight.

- a. Development of a method to accurately estimate decrease in performance in noninvasive and noninterference-type.
- b. Determination of internal correlation between such measuring methods.
- c. Establishment of standards beforehand as to scope of acceptance of the estimated parameters by periods of the flight mission and the types.
- d. Development of a computer algorithm to execute decisionmaking based on the monitoring.

(3) Method

The method is divided into physiological parameter and psychological parameter. The following is an outline of the respective items that are promising at the present and in the future.

a. Physiological area (presently effective)

- (a) Electromyogram: The index for tension level of muscles and the pressing muscle fatigue will be by use of the Fourier conversion.
- (b) Muscle tremor: Detect the changes quantitatively under the various types of physiological stress.
- (c) Target recognition error: Evaluate capability of the pilots coping with target inputting controlled by the computer.
- (d) Hypoxemia: Measure either the hemoglobin saturation or the pO_2 , pCO_2 . In the future, the tolerance limit of the pilot for hypoxia will be indicated by the PCC card.
- (e) Body temperature: Measure temperatures of the skin and deeper area following performance.
- (f) Flight control error: This is desirable as performance parameter.

b. Physiological area (future promising)

- (a) Magnetoecardiogram and electromyogram measurements: Necessity to be of the noninvasion type.
- (b) Vocal cord vibration: Measure the low-frequency tremor element of the human voice as an index for lower performance utilizing that which had already been used in determining if a certain person was telling the truth or not.

(c) NMR (nuclear magnetic resonance): It is necessary to noninvasively measure numerous parameters. If utilized in the aircraft, it will be possible to accurately assess the condition of the energy system and the muscles of the operating pilot.

(d) Heartbeat output: Effective as an index for physiological workload.

(e) O₂ intake and blood flow: The development of laser doppler analysis technology is effective.

(f) Catecholamine: Necessary in development of the noninvasive type measuring method by laser for analyzing catecholamine that is effective as an index for physiological and psychological stress.

c. Psychological approach (presently effective)

(a) Measuring short- and long-period induced electrical potential reactions.

(b) Eyeball movement.

(c) Performance by secondary task.

Items mentioned above will be brought into the cockpit within 5 years, for possible use in realtime monitoring.

d. Psychological approach (future promising)

(a) Magnetic brainwave

(b) Evaluation of the changing method of tactics by the pilot.

(Included in this are information processing strategies, such as, cutting off surplus information and enhancing concentration on attention to necessary matters.) These evaluation methods are also effective in estimating overload and declining performances.

In any case, it is necessary for the research to be directed toward changes in special strategy, in identifying the stress or causing the change, or on the development of strategy evaluation method of aircraft environment. For this purpose, factors such as the following will become necessary: 1) the necessity to conduct a series of experiments to determine the mutual relation between the physiological and psychological parameters; 2) the selection of standards from the results obtained by measurement of parameters; that is, to determine the maximum allowable value in the system or for the mission, and to determine the critical allowable value of the operator; and the application of the decisionmaking theory will become effective for this purpose; and 3) the development of the computer control algorithm, for example, the utilization of the artificial intelligence incorporating various parameters.

(4) Facilities

The existing facilities can be used sufficiently. It will mainly depend on the computer facilities using artificial intelligence. It is necessary that the data base is made considering the balance of the pilot performance by concentrating visual display, and by the change of the control pressure and other parameters as a means of making an aircraft acceptable by the pilots without resistance. The use of the highly reliable air force simulator is effective in conducting research.

(5) Application

The monitoring technology estimating the declining performance of the pilots can be applied to the extremely high-stress missions expected in or after 2000, such as low-altitude missions under inclement weather, strategic reconnaissance and tactical ultra-high altitude missions, long- or short-period missions, and in orbital flights.

The following are three stages of application methods.

a. Hints of the operator

This is the simplest application, which sends visual or auditory signals to the pilot during the mission. The pilot will adjust his action accordingly by such signals.

b. Off-line compatibility

Considering the individual physiological differences of each pilot, by checking the capability, physical strength, etc., of the pilot on a weekly, monthly, and annual basis, and by updating the PCC input data, monitor the pilot to display his maximum capacity. This technique can also be applied to monitor individual differences in information transmission ability.

c. Biocybernetics

This level is the most appropriate and complicated way to approach this problem.

In the on-board avionics the pilot faces in declining performance, he can correct the operation of the aircraft both from display and control by manipulating this mode.

For instance, when the pilot's range of vision becomes narrow, the critical visual display of the display at the center of the console moves and measures are taken not to use the surrounding displays.

2. Estimation Model of Crew Performance

(1) Foreword

The estimated model is very effective in determining to what extent the new strategy or the device can solve the problem regarding performance.

Enhancing this type of model is highly valuable in clarifying problems, in evaluation of solving methods (example: changes in work/rest cycle), in testing and evaluation, minimizing costs, and in reducing dangers in human tests.

(2) Object

Enforce integration of the various models and identification of various gaps (example: chronic influence (daytime) and influence through repeated exposure (acute, prolonged or chronic)).

Conduct integration of respective models--mutual effects of medicine, acceleration, heat factor, pressure, vibration, circadian rhythm, nutrition, dehydration, lack of sleep, etc. This includes the physical, physiological, and psychological models.

(3) Method

Hold domestic/international symposiums on models of human reaction to stress.

Conduct research such as the workload (energy cost) in NOE (nap of earth) flights, in high-G flights, various mission profiles (strategic, tactical, etc.), and the influence on pilots in aerial reconnaissance with minimum support from a remote/secondary base. Conduct research, etc. on stress caused by the pilot himself (smoking, drinking alcohol, participation in parties).

Most important is in conducting models' enhancement in mutual relations of small groups between the stressor and the individuals. Necessary at this time are: a) the development of a data base required for enhancing models; b) the development of experienced and theoretical models suitable for data utilization; c) studying the appropriateness of models; d) expansion of models; and e) enhancing models relative to motivation, leadership, and the influences of training, etc.

Although the starting point of this work must be placed on the study of humans, the study of animals will also become necessary for a certain kind of stressor (example: radiation).

(4) Facilities

It is necessary to compile a listing of the facilities conducting such research. The AGARD panel is also effective. It is necessary to continue such efforts in order to upgrade the models.

(5) Application

This is applicable to all, such as life-supporting developmental programs, tactical, strategic, and transportation scenarios.

3. Prevention of Motion Sickness

(1) Foreword

Much is already known about the cause of motion sickness during flight, and it is no longer a new problem, but it still exists today as a cause in damaging pilot performance. The problem is even more serious since pilots will be exposed to the challenging tasks and motion environment with much greater stress.

There are some medicines effective for motion sickness that have already been developed. However, such medicines have the deficiency of having tranquilizing and side effects that lower the pilot's performance.

Military pilots are required to display maximum capabilities for visual tasks in a dynamic environment that may generate motion sickness. Therefore, it has become necessary to develop effective medications and treatments without any side effects.

At the same time, the improvement of selection method is necessary. Measuring individual sensitivity to motion has existed since early times, but a reliable technique does not yet exist which estimates whether an individual will find a defensive adaptable method against motion sickness during training, and will retain it and not become motion sick during flight.

(2) Object

- a. Exclude individuals unable to adapt to motion environment during the mission, and develop such a method.
- b. Develop effective medicines or treatment procedures so as not to lower pilot performance.
- c. Optimization of the cockpit environment to minimize motion stimulation on vision and the entire body.

(3) Method

- a. Fundamental approach: Conduct research on the neurophysiological process related to the occurrence of the motion sickness syndrome, and also the working location and type of antimotion sickness medicine to establish a new treatment method.

Although initial assessment of new medication should be developed based on a detailed understanding of its applicable type of existing medicine, first, an evaluation will be necessary with animal tests. Such research must be confirmed by laboratory experiments to determine the following:

(a) Motion sickness caused by simple induction stimulation and the effects and effective period of new medication that can control it.

(b) Working mechanism of such medicines.

(c) Studying influence of new medicine on mental work performance.

b. Applicable approach

Improvement in selection procedure through vertical research. Study the history of pilots' motion sickness and compare it with the test results when they were student crews.

It is necessary to develop suitable preventive procedures and techniques for arranging new displays, especially that of the helmet for payload display as it may cause complications between vision and motion of the entire body.

(4) Facilities

It is desirable that the first stage of research be started in the general laboratories by persons experienced in neurophysiological and neuropharmacological techniques and also research in nausea mechanism.

A simple angular and linear motion device, and a more complicated device of 2-3 orthogonal axes that produce a linear accelerating stimulation of over 1 m_s^{-2} low-frequency (under 0.3 Hz) is necessary.

(5) Application

Controlling motion sickness is very effective in the following cases:

a. Training.

b. Low-altitude penetration, especially the change in the dynamic environment that accompanies automation will have direct influence on the pilot decreasing his performance.

c. Reconnaissance: The orbital skip mission will expose crew members to the up and down movements of gravity.

4. Prevention of Spatial Disorientation

(1) Foreword

Although the United States Air Force has been directing its utmost efforts in the prevention of spacial disorientation (hereinafter referred to as SD), and despite education about the dangers and mechanism or through improvement of flight procedures, etc., it continues to lose numerous aircraft and crews in aircraft accidents caused by SD. Considering the enhanced speed and higher operability of future aircraft, the cockpit will naturally become much more complicated and the further expansion of the flight environment as in night

time, bad weather, and high-speed, low-altitude flights will present environments likely to induce SD. Thus, SD prevention will become inevitable.

(2) Research Object

- a. To understand the mechanism of the crew's sensitivity and endurance toward SD.
- b. To develop the means to recognize SD as such under all types of flight conditions.

(3) Approach To Elucidate SD Accidents

- a. Physiopsychological control/action measuring method, and neurophysiological approach. For the former, the identification of conditions or factors that actually lower the control reactions. In the latter, to understand SD appearing as an action by neurophysiological study on the directional information transmitting mechanism (by emphasizing the predominance of the mechanism of nerve information and the directional determination strategy).
- b. Effective double approach
 - (a) Improvement of SD training method for the pilot.
 - (b) Improvement of directional display in the cockpit.

At present, through improved ground simulations, an extremely effective demonstration can be displayed to all pilots, and it is possible for the pilot to control the craft to his satisfaction while receiving SD demonstrations.

On the other hand, the greatest object of the cockpit display improvement is to present motion directional information of the aircraft through the most natural sensory channel other than fovea centralis vision.

(4) Facilities

Conditions to be set as facilities. To have a strong R&D program for sense-psychology about the relation between the faculty of sensation and the directional mechanism. To be deeply engaged in flight simulation technology in order to conduct research on controlling action under competitive indications. Be equipped with the most advanced methods in observation, recording, and analysis of the electrobiological activity in the research of neuro-physiology on directional information transmission. The following facilities are appropriate when they are taken into consideration: AFAMRL, USAFSAM, AFHRL, NADC, AFFTC, MIT Human/Machinery Institute.

(5) Application

Task forces requiring maneuvering of high plane level will mostly benefit by this.

It will be extremely effective, in nighttime, bad weather, air-to-ground, low-level air-to-air strategic penetrations, and also V/STOL aircraft.

5. Extensive Performance During HSSL (High-Speed Low-Level) Flight

(1) Foreword

The expansion of aircraft performance to an advanced form of high-speed, low-level, and topographical avoidance with the motion of six degrees of freedom will bring problems of a new type in control and restriction to both the pilot and the designer.

This chapter is aimed at research on how the pilot can cope with the performance under such an environment of multiple stress to include the near future and the distant future as well.

(2) Object

Forecast of severe, biodynamic environment--maneuvers accompanied by high G, continuous G, vibrations, shocks, and added to this, thermal, atmospheric, and psychological stress--how to maintain optimum performance or how to improve pilot's tolerance under such environments must be included in the R&D program. The object in this research area is to prepare background information for the development of optimum performance in the man-aircraft system. In order to promote this the following are special targets:

- a. To provide seats and restraining devices. To minimize biodynamic coupling working disadvantageously against the control action of the pilot and to prevent injuries when escaping.
- b. To provide controller and controlling methods for the manual, vocal, pedal, nerves and muscles, and nerve/electromyogram system that comes in functionally/passively to the pilot's control without compromise.
- c. To clarify limitation in defensive equipment design to minimize the inconvenience of interface with pilots' equipment.
- d. To provide biological-physiological models of humans facing acceleration stress in the six degrees of freedom.
- e. To provide an evaluation or measuring method for performances. With this it will become possible to compare and evaluate different devices or techniques.
- f. To provide for subdivided and expanded performance using modeled artificial intelligence and biocybernetic systems in the symbolic relation of pilot-aircraft.

(3) Approach

- a. It is necessary to develop a passive and effective restraint method in order to make a direct line for body safety along with a change in the seat angle against diverse continuous accelerating direction. It is necessary to develop a time-series technique that can place the seat in an adequate position in a moment's time.
- b. It is necessary to develop controlling equipment not easily affected by vibration based on the biodynamic model and the actual controller. Further, techniques must be developed for the application of voice control input equipment and nerve/myoelectric signal as a controller monitoring under stress.
- c. As to human endurance under complex acceleration, especially under G y, the respective parts of the body must be described. The head area is particularly weak against a force from the side. It is necessary to collect information relative to the limitation of designs as well.
- d. The development of a structuralized biodynamic, physiological model is an example of a large-scale system that should be developed based on the two-element load matrix and the linear system theory, for example.
- e. Assessing the precise performance evaluation model is necessary from the standpoint of measuring sensitivity. The development of a simple measurement and task similar to physiopsychological measurement with control theory as the base is required.
- f. The expansion of artificial intelligence is required; that is, pattern recognition, subdivided solution of problems, the sensory process (between man and machine) and the gradual control method for the integration of pilot and aircraft to prepare for performance division. It is necessary in the change of pilot performance under severe stress conditions that an automatic task division is permitted by intelligence machine on board.

(4) Facilities

It is necessary to further improve the existing environmental stress simulation facilities to include an extensive scope of mission stress.

(5) Application

- a. A low form sitting position with an interoperative restraint system.
- b. A control with the control intent unaffected by vibration against the dynamic system with a possibility of being decreased by cross-coupling force.
- c. A limit in the proper size as a protective device and its assignment.
- d. Make a model of a human. It is necessary to include therein frequencies of biodynamic and physiological stress generated and the frequency.

e. A technique of high sensitivity to evaluate performance and optimum pilot-aircraft interface system design.

f. Progress in artificial intelligence/cybernetics that would take into consideration the mutual capability of pilot-aircraft under stressful conditions. This will automatically divide the required mission during various existing stresses making it possible for the optimum use of the weapons system.

6. Development of Liberal Man-Machine Interface Without Conventionalism

(1) Foreword

It is required in the mission under consideration at present to place much emphasis on the information processing capacity of the weapons system operation. The expansion for capacity to respond to such requirements will become possible by using free means when the human operator inputs or outputs information. The new revolution in computer technology making remarkable progress in large-scale integration and miniaturization of electronic components will probably offer a new opportunity as an actual application of new means for information transmission.

(2) Object

The targeted effort of this chapter is to improve the information-processing capacity of a human operator by developing an alternative mode of information transmission.

(3) Method

It is possible to receive information from numerous biological sensors.

It is well known that the senses of sight and hearing handle an enormous amount of information, and the sense of touch is also a huge widespread sensory system that receives countless pieces of information related to the positions of aircraft and the weapons system. It is the skin function to conduct stimulation intensity analysis spatially and timely in the form of numerous separate sensory models. Even the sense of small system can be used as a means of information transmission when the contents are not complicated.

The area of interest should be aimed at direct nerve stimulants either by the nerves surrounding the skin electrode or by the central nervous system through the much more complex neuroelectric induction system such as electromagnetic transmission. The electrically stimulated skin surface can be used for the same purpose as the direct mechanical stimulation of the vibration tactile perceptive system. (The monitoring of motion and the position of the weapon, for example.)

Today, the technique of noninvasion type or in stimulating the central nervous system, even though in an invasive type, urgently needs to be developed. However, if miniaturization of data processing hardware is realized as that suitably satisfying the purpose, it should be possible to develop a direct interface between the external physical environment and the internal nerve structure when many problems would be solved.

Attention should be paid to the limitation of the mechanism included in the course of information processing. For the required sensory information, it will be necessary to preprocess artificially taking measures to cope with each piece of sensory information. However, it is necessary that the capability of the operator actually processing the information and making the decisions should be made quantitatively, based on the value added information by the enhancing expansion of the sensor interface. At the same time, it is also necessary to develop it while confirming that it not exceed the ultimate information processing capability of the operator.

There is quite a strong possibility of realizing a coupling to monitor the position of an operator and the mechanism in translating the desire and intention of the operator for realization to the biologically generated information. Among the promising developments of biodynamic effectuators, it is the muscular mechanical, myoelectrical, and neuroelectrical effectuators.

In the first category, the entire mechanism directly controlling the mechanical devices through the voluntary motion of muscles is included. For example, a weapon can be moved by the voice, the muscle tension of the face and the head or by chewing piezoelectrical dental transplanted tissue. It is difficult to do and the analysis of complicated signals requires the activation and control of the myoelectricity. For example, myoelectrical signals can be used to guide aircraft and to discharge weapons. Especially, under the G stress of powerlessness, flight control through spontaneously generated muscle potential is especially effective. In addition, there are many examples of application of neuroelectric signals. The corneal and retinae potential differences guiding the weapon visually toward the target are also such examples.

(4) Facilities

The United States Air Force AMRL and SAM facilities have adequate personnel and equipment to conduct such research. Especially, it is indispensable to have a neurophysiology laboratory and a biotechnology laboratory.

In the first stage of this technology, experimentation using high-class, especially ordered testing animals is an absolute prerequisite and there should be no compromises or sacrifices.

(5) Application

The technology included in the free-type man/machine interface developed at present will allow for application under various mission conditions feared as being under pressure by information transmission load, or under conditions

in which mechanical power or other environmental factors limit or decrease the physical motion of the operator.

Since both the tactical air-to-air mission and the strategic penetration will impose severe information-processing loads on the human operator, it will be more beneficial for the capacity of the operator if value-added sensors and the effective interface are utilized.

7. Expansion of Communication

(1) Foreword

At present, oral communication is an important link in communications among the crew and in the crew communications having command structures.

The present communication system is by no means in a satisfactory condition affected mainly by the environmental factors such as accelerating degree and impact. Further, the jamming of the enemy is more critical and actually the cause of accidents.

In the near future, the development of a communication system without jamming is desired. In such fundamental techniques, a synthetic language will be used at the receiver terminal, but in the current technique the characteristics of the individual speaker cannot be recognized.

The current issue is to make a highly reliable voice control system in order to assist the crew under conditions of heavy workload and high stress.

(2) Object

- a. To prepare an optimum, reliable authority communication channel under all conceivable types of electronic warfare.
- b. To prepare a multiple station/communication system that is extremely faithful to the speaker under all conceivable phases and conditions of operational flight.
- c. To provide a communication system characterized by noise exclusion to heighten the reliability of communications and for the prevention of auditory loss by the crew.
- d. To develop an automatic or semiautomatic communication/voice channel selection system based on order of priority.
- e. To use the same communication system for voice control and voice feedback.
- f. To confirm the adequate means of strengthening the auditory information transmission or, conversely, to lessen the load through visual or vibrating tactile channel.

g. To equip the function that can reliably monitor identification of the speaker and his or her emotional stress conditions.

h. To determine the optimum auditory alarm/visual alarm system using the voice and voice audio component.

(3) Method

Language depiction, equipment analysis, and voice synthesization are rapidly expanding fields along with close joint research with communication engineering and acoustic psychology.

The development of basic research and the analysis of operational mission communication under every stress condition is required in voice analysis for use as a stress monitor.

The power of hearing, as well as the potential influence of low-level chemical action exposure must be evaluated with regard to language formation.

In the course of information processing at the auditory channel, it is necessary to take the necessary measures to cope with all potential jamming operations at the same time in developing jamming capacity for attacking.

(4) Facilities

New main facilities are no longer required, but an extremely well-equipped auditory laboratory with such specialists as acousticians, biologists, and radio engineers is necessary.

(5) Application

As listed under the paragraph on object.

8. Definition of Influence by Multiple Stress and Enhanced Model

(1) Foreword

The operational environment generates a combination of multiple stresses of internal factors caused by the function of the aircraft system crew, and by the external factors threatening the body. The crew will be exposed to such stressors. Further, establishing an operation itself is an abnormal condition to face. It is a change in the work/rest cycle and the sleep pattern, preventive/therapeutic medical action, irregularity in eating habits, etc. These will affect the physiopsychological base line of the crew, and in turn, will result in the decrease of mission performance and in the decrease of mission effectiveness.

Eventually, both the internal and external factors of environmental stressor act mutually on the base line condition of the crew, and will have a different influence simply from the total research conducted individually by laboratory experiments.

For example, vibration, heat (extreme degree of), glare, workload, and information processing load are included in the internal environmental stressor, and the spotted windshield by laser, high-G maneuvers to avoid missiles and ground fire, exposure to chemical/biological reactions, and exposure to ionized or nonionized radiation, etc., are also included in the external environmental stressor. Effects of such multiple stress have not been understood up to this time, but recently significant efforts have been directed toward research into making theoretical models, full-scale simulations, and systematic and parametric analyses.

(2) Object

The following three basic objects are necessary in resolving the multiple stress environmental problems anticipated in the future aircraft system.

- a. To describe, classify, and analyze the anticipated stressor to be encountered and to conduct research through experience.
- b. Data obtained from experimental research are necessary to be included in the theoretical model so as to allow explanation of mutual action effects of the linear and nonlinear types.
- c. It is necessary to confirm the theoretical model under operational conditions or by full-scale simulation.

The final target is to study countermeasures for multiple stress under operational environment by fully understanding and storing abundant knowledge concerning the influence of multiple stressors on human faculties in the aeronautical environment.

(3) Method

- a. To determine every conceivable internal and external stressor anticipated in the mission under consideration.
- b. To delineate variables having influence on the physiological and psychological bases of the crew.
- c. To define a standard for human faculties in the aeronautical environment.
- d. To establish a classification method for the physiological and psychological base line and measuring the human faculty in combination with stressors in the aeronautical environment.
- e. It is necessary to conduct studies through experience of the aforementioned parameter and a special survey, and a high degree, operationally realistic connection is also needed. Further, such data must be integrated into a large-scale system model led by the compound system theory.
- f. The interoperable mode must make the complicated human integrating biodynamic psychophysiological system structure its base.

The structural model must be combined with the actions of three basic stress parameters (internal, external, and physiological/psychological bases) using homogeneous dependent variables.

Interoperable examples must be essentially dynamic. They must be such that explain the time-series influence variables in relation to the temporary reaction of the subsystem itself.

(4) Facilities

A large-scale biodynamic research simulation is necessary to make possible the application of the aforementioned three stress parameters.

A new approach should be started for a centrifugal force generation device equipped with the capacity to generate a very high degree actual multiple stress or through the development of national level stress facilities.

(5) Application

The multiple stress model can be used to decrease stress associated with the operational environment.

This model will prepare for the items required in the environment, the cybernetic performance expansion system, and the minimum stress/maximum efficiency mission plan.

The above was an explanation based on research results to date on how to expand performance while decreasing man's stress. Next time, it is planned to explain the human side of protection accompanied by performance expansion, especially the equipment and countermeasures from the side of the aircraft.

2055/9365

CSO: 4306/2528

OUTLOOK FOR CITY GAS INDUSTRY IN 21ST CENTURY DISCUSSED

Tokyo DENKI TO GASU in Japanese Jan 87 pp 13-17

[Report by the Japan Gas Association on "Long-term Projection of the City Gas Industry--Outlook for the City Gas Industry Toward the 21st Century"]

[Excerpt] In order to study the ideal mode of Japan's energy structure looking toward the 21st century and to study policy issues required, the Agency of Natural Resources and Energy under MITI set up the 21st Century Energy Study Committee in November 1985. It proceeded with its study over the last year and summarized a report on "The 21st Century Energy Outlook" in the middle of November 1985. Meanwhile, in order to convey the subjective outlook and opinion of the private sector to this agency, the Energy Overall Promotion Committee set up the Energy Industry Long-term Outlook Special Committee in November 1985, organized a subcommittee for each energy-related industry, and conducted investigations and studies required. As a result the committee summarized a report on "Energy Industry Long-term Outlook" at the end of October 1986.

The Japan Gas Association highly evaluated MITI's formation of energy outlook toward the 21st century and agreed to the main points of the committee report. The association considered it necessary to formulate the long-term outlook of the energy industry from overall and systematic standpoints with this as a momentum and set up a "long-term Outlook Study Subcommittee (Chairman: Ikuo Anzai, senior managing director of Tokyo Gas Co., Ltd)" under the Planning Committee of the association in December 1985. Also, the association authorized the subcommittee as the Overall Energy Promotion Committee, proceeded with studies of the future mode of the city gas industry and also of the ideal mode of Japan's energy structure and policy, and filed a report on "Outlook for the City Gas Industry toward the 21st Century."

A summary of the report follows:

II. Worldwide and Japanese Reserves of Natural Gas

The proven reserves of natural gas in the world are presently 99 trillion m³, and correspond to 90 percent of those of petroleum. Also, the production of natural gas is 1.8 trillion m³, occupies 20 percent of that of the primary energy sources in the world, and corresponds to almost half of that of petroleum. As a result, the ratio of reserves to production is 54 years. The ultimate recoverable reserves are said to amount to 300 trillion m³. Thus it can be said that there are few limitations on the supply capacity of natural gas.

In light of circumstances in the West where the utilization of natural gas is advanced, natural gas can be said to be an energy source having a possibility of rapid growth, if infrastructures and effective policies, etc., are properly arranged.

In Japan, recent years have seen a steady increase in the consumption of natural gas; Japan has ranked sixth in the world's consumption. However, the characteristics of the Japanese market are different from those of the Western market in respect of the following:

- 1) The ratio of consumption of natural gas in the primary energy sources in Japan is very low (9.4 percent in 1985), compared with that in the West.
- 2) Conversely, the ratio of consumption of petroleum is high (56.7 percent).
- 3) The consumption of natural gas in the electric power industry is large.
- 4) Dependence on the imports is very high; all imports are in the form of LNG.

Most importantly, therefore, Japan must promote the expansion of utilization of natural gas as an important core of petroleum alternative energy sources with priority given to LNG, in order to attain the best energy mix.

Next, in light of the world's natural gas resources from an ultralong-term standpoint, the "Terrestrial Deep Gas Theory" that large amounts of unorganic methane formed at the time of birth of the earth exist deep in the earth is advocated, as against the conventional organic theory that natural gas has been formed as a result of chemical change in animals and plants. The former gas theory has recently attracted attention. If this theory is right, the earth's methane resources becomes huge, and gas is likely to be an inexhaustible energy source.

III. Possibilities and Problems Concerning LNG

The amount of the Japan's import of LNG expanded rapidly, at an annual rate of 19 percent over the last 10 years under the joint import system of the power and city gas industries. In 1985, the import amounted to 27.83 million tons and the ratio of supply of LNG among Japan's primary energy sources exceeded 9 percent.

In the electric power industry where 80 percent of Japan's LNG demand exists, LNG-fired power already accounted for 21 percent of the total generating capacity. The electric power industry aiming at the best mix of power source ranks nuclear power and coal as the base load, and ranks LNG as that for peak and middle load. Therefore, considerable growth of LNG demand cannot be expected.

Meanwhile, the three leading companies played a key role in moving ahead with the switch-over of supply for city gas to LNG. However, LNG accounted for 79 percent of such companies' demand, arriving almost at the maximum level. Therefore, increase in demand for LNG for commercial and industrial purposes is indispensable for the future growth of LNG demand.

The volume of 32.6 million tons for 1990 and that of 37.5 million tons for 1995 which are forecast as LNG demand toward 2000 are slightly lower than the volumes in "Forecasts for Long-term Energy Demand and Supply" publicized by the government in November 1983. On the other hand, an LNG demand of 42.3 million tons for 2000 is slightly over that forecast by the government.

In the meantime, only projects which are currently on line and for which contracts have been awarded satisfy demand up to half of the year 1990, from an LNG supply side standpoint. There will be no problem with regard to the supply capacity of LNG as a large number of projects thereafter are studied.

Therefore, the following are keys to the future growth of LNG demand in Japan. First, a price level of LNG as is competitive with that of fuels such as heavy oil, used in the industrial and commercial areas must be maintained for city gas purposes, and also such price level of LNG as can be in competition with that of nuclear power and coal, must be kept for electric power generation. Second, it is important to change the rigid transaction conditions set out in the "Take or Pay" provisions to the flexible conditions. The cost of LNG must be reduced as a result of technological development in the liquefaction and transportation of natural gas and also streamlining of LNG projects must be promoted, in order to fulfill the above two requirements.

IV. Overall Evaluation of City Gas

Energy sources in the 21st century must meet requirements of the age for security, cost, and quality. Therefore, LNG must be seen as a primary supply of city gas from these aspects.

First of all, long-term stability is secured for the following reasons:

- 1) The stable operation of LNG projects can be expected since they require huge amounts of capital investment, and sellers and buyers conduct specified and long-term transactions.
- 2) The Pacific Ocean countries whose political situation is more stable than the supply sources of petroleum have most of the LNG supply sources.
- 3) Furthermore, the long-term stability in connection with the production and supply systems of city gas is secured.

Next, leading gas companies have introduced LNG to streamline facilities and also to reduce the number of their workers, in the production aspect, and have proceeded with efficiency measures such as increasing the gas supply capacity, etc., as a result of conversion into natural gas, in the transportation aspect. Eventually, fixed costs incurred in the production and supply of city gas tend to decrease over time.

Lastly, the city gas companies have established integrated overall safety systems from the transportation and receipt of LNG to the production and supply of gas. As a result, it has been possible to maintain the safety level of gas standing on a par with that of electricity, at the time of its use. Also, of all hydrocarbon energy sources, natural gas emits the least amounts of

hydrocarbon dioxide, sulfur and NO_x, etc., and is a very excellent energy source for providing environmental protection (greenhouse effects, acid rain measures, etc.). Accordingly, natural gas can fully satisfy high-quality needs, combined with the excellent features of energy saving, etc.

V. Issues Concerning City Gas Industry

As mentioned, city gas is provided with basic conditions enough to meet the future needs. However, the following issues must be tackled to meet the changes of the new age, i.e. the sophistication of the economic society and the diversification of needs.

The first issue is deregulation at the city gas industry. It is necessary to move ahead with deregulation considering the following aspects:

- 1) Deregulation of gas charges in the commercial and industrial areas
- 2) Deregulation for the specified supply of electricity involving the commercialization of new technologies such as cogeneration
- 3) Flexibility of regulation for expansion into businesses other than the city gas industry

The second issue is to further promote measures for strengthening the structure of the local city gas industry, such as the promotion of introduction of natural gas, etc., over a long period of time, with the Natural Gas Introduction Promotion Center established in 1985 playing a key role.

The third issue is the further improvement in the importation and transportation systems for natural gas toward the 21st century. Specifically, nationwide pipeline networks must be properly arranged, and the submarine transportation of natural gas by means of pipelines from overseas oil fields also must be studied.

The fourth big issue is the solution of various issues concerning the city gas industry and the promotion of natural and city gas-related technology development as a basis for ensuring the long-term growth of the industry. Specifically, there are several promising gas-related technological issues as well as issues of exploratory and excavation technologies for terrestrial deep gas with huge reserves said to exist deep in the strata. Also, issues on city gas-related technologies are the development and proliferation of technologies in connection with the demand side of city gas, etc., such as gas engine heat pumps, cogeneration and fuel batteries, etc. Issues on a large number of technologies whose development is expected in the production, supply and safety areas of city gas are before the city gas industry.

VI. Forecast for Japan's Long-term Energy Demand and Supply

The city gas industry has of its own completed trial calculations of the long-term energy demand and supply toward 2000 and 2030 and 2-3 percent thereafter. As a result, the annual growth rate of primary energy is deemed to be 1.6 percent

Table 1. Demand Forecast for 2000 and 2030

	エネルギー・シェア (1) (%)			年平均伸び率 (2) (%)	
	1984	2000	2030	2000 / 1984	2030 / 2000
(3) G N P	—	—	—	4	3—2
(4) 一次 エネルギー	—	—	—	1.6	1.0
(5) 二次 エネルギー	—	—	—	1.1	0.6
(6) 都市 ガス	4.0	5.8	10.0	3.6 (2000/ 1985)	2.4
(7) 電力	15.9	21.9	31.1	3.2	1.8
(8) 石油 製品	63.9	52.2	35.0	▲ 0.1	▲ 0.8

Key:

1. Energy share
2. Average yearly growth rate
3. GNP
4. Primary energy
5. Secondary energy
6. City gas
7. Electricity
8. Petroleum products

Table-2 Primary Energy Demand and Supply Balance

By Energy source	1985		2000		2030	
	Actual Number	Component ratio(%)	Actual Number	Component ratio(%)	Actual Number (Hundred Mil. kl.oil equivalent)	Component ratio(%)
Petroleum (domestic petroleum) (LPG)	249 mil.kl.	56.7	260 mil.kl (600,000 kl) (21 mil.t)	46.7	1.78	24
General			24.2 mil.kw			5
Hydro Pumping-up	34.53 mil.kw	4.9	22.9 mil.kw	5.1	0.35	
Geothermal	460,000 kl.	0.1	1 mil.kl.	0.2	(included in the number of new energy sources, etc.)	
Coal (steam coal)	110.94 mil.t	19.1	150 mil.t (76 mil.t)	19.3	1.89	25
Nuclear	24.69 mil.kw	9.5	59 mil.kw	16.4	2.15	29
Natural gas (Domestic Portion) (LNG)	41.3 mil.kl.	9.4	63.4 kl. (3.5 billion m ²) (42.3 mil.t)	11.3	1.00	13
New Energy Sources, etc.	1.28 mil.kl.	0.3	5.7 mil.kl.	1.0	0.32	4
Total supply	438.8 billion kl.	100.0	560 mil.kl.	100.0	750 mil.kl.	100

Table 3. An Overall Table for City Gas Demand Forecast

	1985	1990	1995	2000	(2) 年平均伸び率%			
					90/85	95/90	2000/95	2000/1985
(3) 家庭用	6,743	7,115	7,901	8,768	1.1	2.1	2.1	1.8
(4) 一般業務用 (含コージェネレーション)	2,156	2,505	3,007	3,637	3.0	3.7	3.8	3.5
(5) ビル冷暖房用 (含ガスエンジンヒートポンプ)	704	1,141	1,950	3,141	10.0	11.3	10.0	10.5
(6) 工業用 (含産L)	2,329	2,935	3,897	4,868	4.7	5.8	4.5	5.0
(7) 販売量計	11,932	13,696	16,755	20,414	2.8	4.1	4.0	3.6

Key:

1. (unit : million m²/10,000kcal)
2. Average yearly growth rate
3. Residential
4. General Commercial purposes (including the co-generation purpose)
5. Building air conditioning (including gas engine heat pumps)
6. Industrial (including industrial LNG)
7. Total sales

and 1 percent respectively. Also, the annual growth rate of secondary energy is estimated at around 1.1 percent up to 2000 and also at around 0.6 percent thereafter (Table 1,2).

Demand for city gas among the secondary energy will steadily expand in the thermal energy demand areas, and city gas is likely to advance into such new demand areas as gas engine heat pumps and cogeneration, etc. Consequently, favorable annual growth rate of 3.6 percent up to 2000 and that of 2.4 percent thereafter can be expected (Table 3).

The major characteristics of demand forecasts for city gas up to 2000 are as follows:

- 1) Demand for household purposes remains at the small growth rate of 1.8.
- 2) However, demand for industrial purposes, primarily for industrial LNG, will steadily expand at the annual rate of 5.0 percent.
- 3) Increase in the demand for gas engine heat pumps and cogeneration for air-conditioning in buildings is estimated.
- 4) As a result, the overall annual growth rate is estimated at 3.6 percent.

Up to 2000, LNG will account for 74 percent of city gas supply in response to such a demand growth, and the volume of consumption of LNG is estimated at 11.7 million tons.

Subsequently, the volume of introduction of LNG by the city gas industry will increase. However, it is forecast that the ratio of natural gas will stay at around 85 percent by 2030, since fixed amounts of LPG will be needed for increased heating of natural gas and coverage by SNG is anticipated.

VII. Future Development of the City Gas Industry

In light of the foregoing long-term demand and supply for city gas, strengthening of price competitiveness, promotion of technological development, promotion of introduction of natural gas by the local gas industry and also relaxation of various regulatory requirements will be necessary for achieving the future greater growth of the city gas industry.

In seeking a solution to these issues, the future city gas industry must free itself from a conventional single product supply type of industry, and expand into peripheral fields in order to make new rapid progress as an overall city life industry, and also must establish a satisfactory international cooperative system in each field of management and technology, and transfer the results of such development.

This report is intended to offer suggestion to the city gas industry and allied fields, because it has extensively focused on various problems primarily with the city gas industry and discussed the ideal mode of the industry from a long-term viewpoint. As details of the report have been studied within the limited time and organizations, however, this report must be a starting point for future discussion rather than the conclusion.

EXCIMER LASER, RELATED TOPICS REPORTED

Tokyo OPTRONICS in Japanese Oct 86 pp 57-59

[Article by Shuntaroh Watanabe, Institute for Solid State Physics, University of Tokyo: "Special Report on Topics of Optical Technologies at International Conferences"]

[Excerpt] Topics Related to Excimer Laser

I will now describe topics related to the excimer laser and its application. These topics are extracted from the CLEO '86.

Recently, the excimer laser has come into the age of application, and the number of R&D works with definite purposes has increased. The field is broadly classified into the following four items: 1) development of a large-scale system with the aim of nuclear fusion and X-ray laser; 2) development of an industrial high-repeat and high-average output laser; 3) kinetics; and 4) excimer laser application. I will describe these four items.

1. Development of a Large-Scale System

The shorter the wavelength, the more the absorption efficiency of laser light according to laser plasma and the generation efficiency of soft X-rays rise. Also, it can be expected that the internal efficiency of the excimer laser will be more than 10 percent and the system efficiency will be several percent. The LASL (Los Alamos Scientific Laboratory) is constructing a 10 KJ class aurora system (THF4) as a driver for nuclear fusion. A carbon dioxide laser system will be frozen as soon as it is completed, and will be entirely transferred to an excimer laser system. Figure 1 shows the conceptual drawing. This system successively incides 96 beams with a pulse width of 5 ns in an amplifier by using a slight difference among incident angles and a delay of 5 ns, and effectively takes out energy from a gain width of 500 ns. Theoretically, this method is simple, but it requires a huge optical path with a length of hundreds of meters, and a long passage purged with nitrogen and shielded with temperatures with a view to correcting the deviation of the optical path caused by temperature difference and of the absorption caused by ozone contained in the atmosphere. The 96 beams are focused simultaneously on a target from both sides. From the standpoint of the use of this focusing method, it can be appreciated that the compression according to X-rays is targeted. According to my view, obtained from a visit to the above system, it

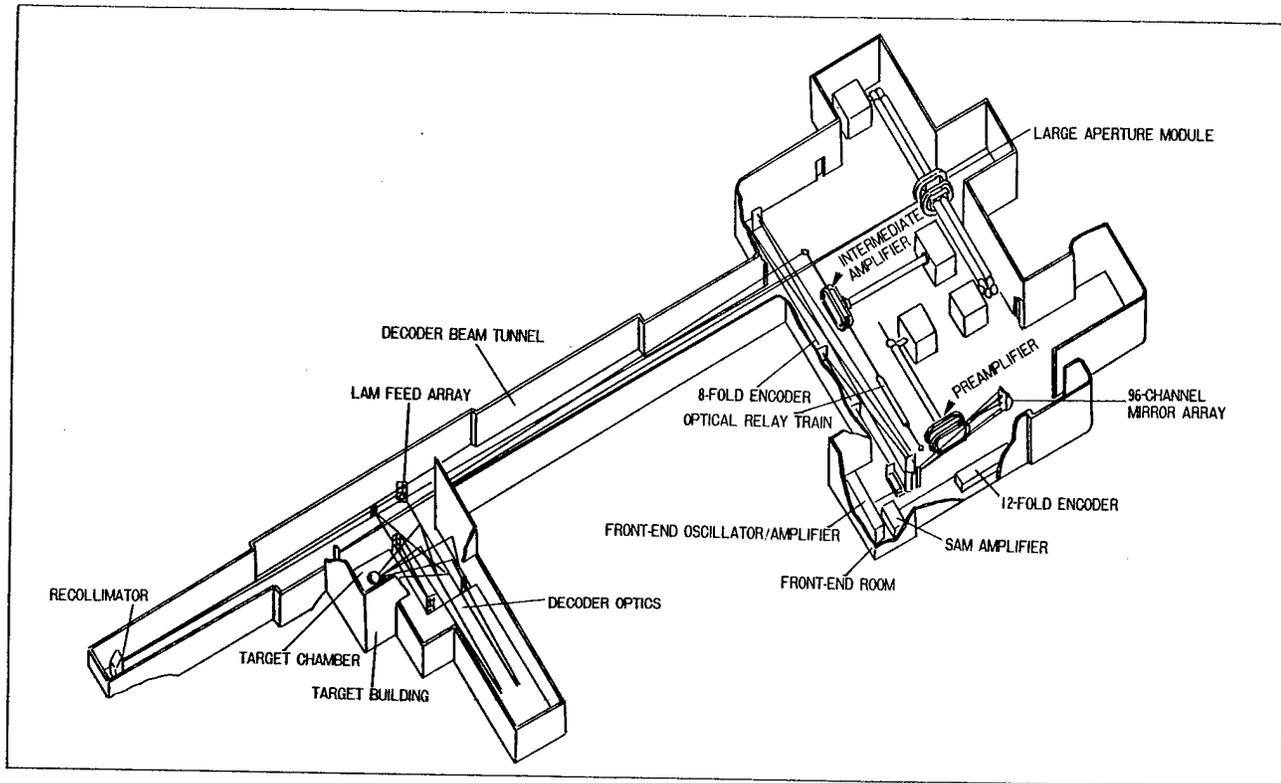


Figure 1. 10-KJ Class KrF Laser System

seems that the system still had some problematical points which should be solved before it is completed.

The Lutherford Research Institute in England completed a 200-J class amplifier several years ago, and has performed experiments on pulse compression according to multiple beams by using this amplifier (THF5). As staff of the Lutherford Research Institute is proud of the amplifier, it seems that the operating rate is considerably high; but the amplifier is prototypal and small scale as an amplifier for nuclear fusion. According to Dr Shaw's opinion, the transference to X-ray laser will be entirely carried out, and simultaneously the ps (picosecond) amplification will be carried out in the future. Besides, the Lutherford Research Institute has obtained excellent research results on X-ray lithography, X-ray microscope, and EXAFS (extended X-ray absorption fine structure) by using X-rays generated from excimer laser excitation plasma in common use in England (TUS1). Also, the Electrotechnical Laboratory of the Agency of Industrial Science and Technology (AIST) of MITI has reported an electron beam excitation amplifier (THK34).

Apart from the system for nuclear fusion, a ps TW-class excimer laser has come into the limelight.

2. High-Repeat and High-Average Output Laser

Unlike the single-pulse, high-energy laser for scientific research work, the industrial excimer laser requires high-average output and long life. Efforts of respective manufacturers are outstanding in this field. Rumonix Co., Ltd., has obtained 40 watts (150 hertz) efficiency of 4 percent, and gas life of 10^8 shot by using KrF and laser on the market (TUR6). With regard to average output, XMR Co., Ltd., has obtained 300 watts (500 hertz) and 157 watts (500 hertz) by using XeCl and KrF, respectively (WK30). Lambda Co., Ltd., has already put the 100-watt-class (250 hertz) laser on the market. All lasers with more than 100 watts employ a magnetic switch. The life of the Thyatron is gradually drawing close to the value of 10^9 to 10^{10} shot by jointly using a magnetic switch and by modifying the Thyatron itself. Up to now, various traps and dust collectors have been used and the method of blowing gas on windows has been adopted as measures against deterioration of the laser gas and optical elements. Research on impurity-forming processes have been conducted continuously in order to further lengthen the life of the Thyatron (TUR6). There are many cases in which a light source which is as close to a CW (continuous wave) light source as possible is required in the field of application of laser to semiconductor process. Experiments on approach of the light source to the CW light source are being performed by increasing the pulse width to more than 200 ns and by carrying out high repetition (more than 1 kilohertz) (TUR1 and TUN5). At present, lasers with a small output of about 1 kilohertz have already been put on the market, but it can be considered that high-repeat and high-average output lasers will be put on the market in the future.

3. Excimer Laser Kinetics

Research on excimer forming process, absorber, etc., has long been conducted. Recently, the rise in efficiency of electron beam excitation laser has created a sensation. Up to now, Ar has been used as a diluent gas for KrF laser, but the following idea has been advocated: the direct excitation of Kr/F₂ will enhance the efficiency. Also, when Kr is used from the standpoint of stopping power of electron beams, the burden of windows and foils will be lightened because of 1 atmospheric operation. The rise in efficiency according to Kr depends chiefly on excitation density, and is effective for the case when excitation is weak and formation of absorbers does not become a problem. Eventually, the highest efficiency has been obtained at a proper ratio of Ar/Kr because of the excitation intensity (TUN1). Experiments on ArF, which are similar to the above experiments, are also being performed (TUN2). The National Research Institute in the United States has revived kinetics of XeF with consideration to the fact that XeF is superior to KrF in propagation characteristics in the air (TUN3 and TUN4).

4. Excimer Laser Application

The new topic related to excimer laser application is an experiment on use of XeCl laser with relatively large pulse width in operations on the inside wall of blood vessels (TUA1 to 4). The use of CW lasers will damage even normal tissues because of temperature rise. Also, the use of other pulse lasers

(YAG1.0.6, YAG1.0.53 micro, etc.) will destroy peripheral tissues. The problem lies in a UV (ultraviolet ray) fiber which guides the laser light into blood vessels. The longer the pulse width of lasers, the more the fluence (J per square centimeter) which passes through the fiber can be increased. There was another report on loss of fibers for excimer laser, and if the distance is short, even KrF can be used sufficiently (TUK16).

With regard to the semiconductor process, the application of excimer to etching (TUJ1 to 4), deposition (TUO2 and TUK6), and doping (TUO1) has been generalized. In particular, a symposium on actual semiconductor manufacturing unit was held at a special session not mentioned in the premanuscript, and appealed to the auditors. The units related to the excimer laser were the doping unit made by XMR Co., Ltd., pattern generator made by GCA Co., Ltd., and mask aligner made by Karl Seuss. Recently, lithography employing the excimer laser as a light source has created a sensation, and in the SPIE (Society of Photooptical Instrumentation Engineers) held in March, AT&T Bell Laboratories reported the fact that a line width of 0.4 micron has been obtained by using a stepper unit employing KrF. GCA Co., Ltd., is also related to this project, and when the company was questioned about the period of practical use of stepper units, the company replied, "It is a matter of time." In the system of AT&T Bell Laboratories, the laser has been banded narrowly for the purpose of preventing the lens system from chromatic aberration. In contrast, Toshiba Corp. recently has obtained a line width of 0.35 micron by using a lens and KrF with a spectrum width of several angstroms as a light source. The chromatic aberration of this lens has been corrected. I was impressed by the fact that of the semiconductor processes, the use of lithography units would be most close to widely practical use. The resolving power has been enhanced by using ArF because the reflective projecting system made by Karl Seuss Co., Ltd., has no problem of chromatic aberration.

In addition, the application of the excimer laser to laser radar equipment (FBI) and underwater communication apparatus (WMI) has been reported.

I was impressed by the fact that the R&D of both large-scale scientific research and industrial excimer lasers is going toward success. In particular, it is expected that the excimer laser will be used in the industrial world in the future.

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INDUSTRIAL RESEARCH FACILITIES PROFILED

Kawasaki Heavy Industries

Tokyo NIHON GENSHIRYOKU GAKKAISHI in Japanese Jun 86 pp 36-37

[Article by Fumiyoishi Kanaya, Technical Research Institute, Kawasaki Heavy Industries, Ltd.: "Research Institute Introduction Series 13--Technical Research Institute of Kawasaki Heavy Industries, Ltd."]

[Text] I. Preface

The Technical Research Institute of KHI (Kawasaki Heavy Industries, Ltd.) has a long history, and it began as a technical research office in the Kobe Plant in September 1948. In 1957, the organization of the technical research office was changed to the present organization, and the technical research office was renamed "Technical Research Institute" together with the change of the office organization. It can be said that the foundation of the present Technical Research Institute was laid at that time.

Subsequently, the organization was completed and the number of staff was increased in accordance with the trends of the times, and in January 1975, the Technical Research Institute was transferred from the site of the Kobe Plant to the Akashi Plant.

The Technical Research Institute conducts R&D of basic technologies, and wrestles with the development of new products as the mainstay of R&D work of all products of the KHI. In addition, it gives positive support to the development of products such as various types of equipment and plants in the land, sea, and air fields which cover nuclear power, air and space, vehicles, bridges, chemistry and iron manufacture, ships, and robots.

II. Outline of Technical Research Institute

At present, the Technical Research Institute consists of 2 departments, 11 research offices, and 1 project office (Figure 1), and has a staff of about 300. It has been decided in principle that each time the development of a new product is proposed, a project team will be organized. Recently, the Technical Research Institute has aggressively branched out into such fields as space technology, biotechnology, laser technology, and cryogenic technology in response to the needs of the times, and into fields which can be

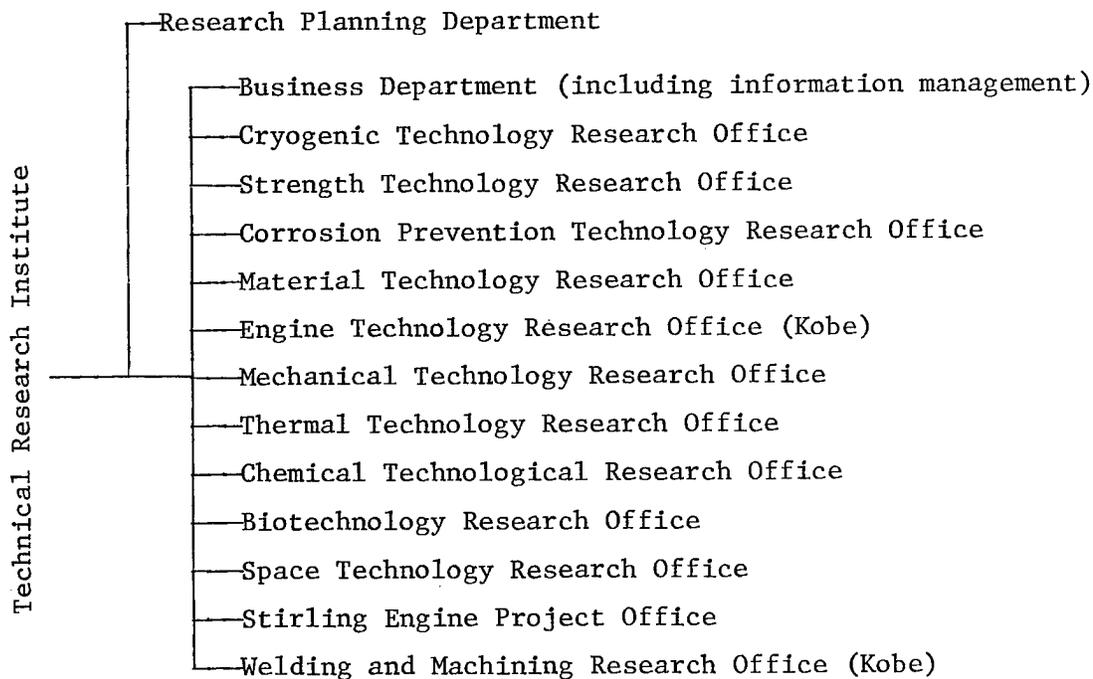


Figure 1. Organization of Technical Institute

called Basic Technology for KHI's Products. Technology related to energy such as nuclear power and coal is being developed powerfully and effectively by weaving in new technologies being used in these fields.

Also, KHI actively carries out research work, mainly energy related, in collaboration with other companies and the number of research projects now being carried out by the Technical Research Institute is 10-odd.

The research facility of the Technical Research Institute, with a total site area of 40,000 m², consists of the main building including laboratories, the main laboratory building, and other laboratory buildings for equipment such as a cryogenic tester, Na loop, coal/water slurry unit, wind tunnel for structures, fluidized bed, He loop, heavy oil reformer, hydrogen storage, large oscillating table, and large scale fatigue tester. These buildings are equipped with various evaluation testers and demonstration test equipment necessary to develop comprehensive technologies extending over the land, sea, and air fields. For example, Photograph 2 [omitted] shows a large oscillating stand made by KHI which can simultaneously apply horizontal and vertical vibration to an object, and is used to perform aseismic experiments for piping systems, equipment, and plants. Photograph 3 [omitted] shows a wind tunnel used to ensure the wind safety of bridges and structures and to explain the atmospheric diffusibility of flue gas and off-gas. This kind of wind tunnel occupies a very high rank in the world as to scale and performance.

With regard to nuclear experimental facilities, in addition to the above-mentioned Technical Research Institute in the Akashi Plant, KHI has welding and thermal processing facilities (for example, a 100 kw electron beam welding machine and a 5 kw CO₂ laser oscillator) in the Kobe Plant and experimental facilities for high-temperature machine and tool materials in the Kawasaki Plant.

III. Development of Nuclear Power

KHI has participated positively in the development of nuclear power in Japan since it was in charge of construction work of the Tokai No 1 Reactor of the JAPCO (Japan Atomic Power Co.), the first commercial nuclear power plant in Japan.

1. Technology for New Reactors

KHI has participated in the FBR (fast breeder reactor) project of the PNC (Power Reactor and Nuclear Fuel Development Corp.), in the FBR projects of electric power companies, and in the multipurpose HTGCR (high-temperature gas-cooled reactor) of the JAERI (Japan Atomic Energy Research Institute). It has stored and completed the data on basic technologies for sodium, heat transfer fluidization, high-temperature structural material, radiation shield, ISI (in-service inspection), remote control, purification of cooling material, nuclear heat design, helium, and graphite, and has, of course, tried to reduce the cost of plant design. The heat transfer fluidization test loop shown in Photograph 4 [omitted] and the He loop shown in Photograph 5 [omitted] have been constructed, and are being used to master these basic technologies.

2. Nuclear Fusion Reactor

KHI participates in the development of a nuclear fusion reactor, and has been conducting R&D of blanket neutronics, first wall action, lithium oxide and tritium handling technology, and cryogenic technology.

3. Fuel Reprocessing Technology and Decommissioned Reactor Dismantling Technology

KHI is developing disk cutters while cooperating in the development of technologies for dismantling the JPDR (Japan Power Demonstration Reactor) of the JAERI and for reducing hulls for the reprocessing of fuel.

IV. Conclusion

Up to now, the Technical Research Institute has carried out technology development, mainly to support the business office, and has attached importance to the basic and elemental technologies. It has greatly contributed to the field of welding technology and stress analysis. In addition, the Technical Research Institute has recently made efforts to develop new technologies in the field of the so-called "High Technology" in anticipation of the needs of the times, and has played the leading role in the development of new products.

Mitsubishi Heavy Industries

Tokyo NIHON GENSHIRYOKU GAKKAISHI in Japanese Jul 86 pp 45-46

[Article by Kazuhiro Shiraki, chief, Takasago Research Institute, Mitsubishi Heavy Industries: "Research Institute Introduction Series 14--Takasago Research Institute of Mitsubishi Heavy Industries, Ltd."]

[Text] I. Preface

In recent years, economic conditions have changed sharply. MHI (Mitsubishi Heavy Industries, Ltd.) has continued efforts day and night to contribute to the progress and development of the society in these economic conditions. Therefore, technical development work has acquired greater importance. The company has been trying to complete the research system while conforming to such a situation. The MHI's research institute consists of five research institutes (Nagasaki, Takasago, Hiroshima, Yokohama, and Nagoya) which are under the direct control of the Technical Division, a system technical department, and a production technology department. They are buckling down to the development of new technologies in cooperation with each other. This article describes mainly the Takasago Research Institute which is in charge of research on nuclear power.

Takasago Research Institute is backed by its long history and glorious tradition extending over 80 years, has been engaged in the R&D work in various fields, and has greatly contributed to the progress of Japan's heavy chemical industrialization since it began as a laboratory section of the MHI's former Kobe Dockyard in 1908. Takasago Research Institute was started as an independent section called, "Kobe Research Institute" which was put under the direct control of the head office at the time three Mitsubishi companies were integrated in 1964. In 1973, up-to-date facilities necessary to conduct research on nuclear power plants were constructed and centralized in the present Takasago district, and in the next year, 1974, these facilities were named, "Takasago Research Institute" after the local district.

Takasago Research Institute has contributed to the development of Japan's nuclear power as the main research institute for the development of MHI's nuclear research for 10-odd years since 1974. In addition to research on nuclear power, Takasago Research Institute is engaged in the development of various product fields such as turbo-machines, environmental equipment, construction equipment, space and oceanographic instruments, biotechnology, robots, and electronic equipment.

The following introduces the main research on nuclear power being conducted by Takasago Research Institute. Takasago Research Institute is buckling down to the development of the APWR (advanced pressurized water reactor), and the improvement of the next-generation reactor, in addition to research on modification of PWR (pressurized water reactor) plants. Also, Takasago Research Institute is promoting the development of the FBR (fast breeder reactor), the nuclear fusion reactor, as well as nuclear power peripheral equipment, and reprocessing equipment.

II. R&D Work in the Nuclear Power Field

1. Research on Corrosion of Materials for Nuclear Plants

Takasago Research Institute is buckling down to the modification of materials which can withstand special conditions such as high temperature, high pressure, and radiation exposure, because nuclear plant equipment employing these materials is used in these special conditions. It is also performing the brittle fracture test for very thick materials for pressure vessels and the corrosion and corrosion-fatigue test for materials used in the in-pile structure, heat-transfer piping for steam generators, fuel systems, and secondary system equipment, by using a large test loop which simulates the reactor environment. In addition, a hot laboratory at Tokai Mura in Ibaragi Prefecture is performing the surveillance test for irradiation test pieces to evaluate the brittle fracture test.

2. Research on Thermal Fluidization Performance and Nuclear Power Plants

Takasago Research Institute is conducting R&D of thermal fluidization performance of primary system equipment such as the in-pile structure and steam generators, and secondary system equipment such as moisture separators, deaerators, and condensers, to enhance the reliability and performance of nuclear plants. Also, it is conducting the development and verification test of simulation codes for cases when the entire plant system is in a transition period or an accident occurs in the plant system. On the other hand, it is continuously conducting various research linked to safety of nuclear power plants.

3. Research on Structural Strength

Takasago Research Institute is conducting research to enhance reliability and safety of main equipment such as pressure vessels, piping system, and valves, by using the most recent structure analysis technologies such as elastoplastic destruction dynamics and the probability finite element method. At present, it is also evaluating the PTS (pressurized thermal shock) of nuclear reactor vessels and the LBB of piping systems, and is constructing large testing equipment to test them.

4. Research on Oscillating Stand and Aseismatic Technology

For about 10 years the Gakasago Research Institute has been performing aseismatic experiments by using the largest private oscillating stand with a dead-weight capacity of 100 tons, and has striven to raise the level of aseismatic design technologies for nuclear power equipment and systems. In recent years, it has conducted research on vertical earthquakes by using a three-dimensional oscillating stand made by modifying the large oscillating stand. Also, it has enhanced the reliability of nuclear plants by conducting research on technology to analyze the vibration of fluid in tube (pipe) banks such as a fuel assembly, and in heat-transfer pipes of steam generators.

5. Research on Electronic Control Technology

Takasago Research Institute is buckling down to research on practical use of eddy current flaw detection, ultrasonic flaw detection, electromagnetic ultrasonic wave flaw detection, and electric resistance flaw detection, because the nondestructive inspection technology is indispensable for maintaining the integrity of nuclear plants.

Also, it is carrying out the development of more sophisticated technologies for following load control, for control and electronic equipment, resistance to the environment, and for technologies to diagnose abnormalities in plant equipment employing knowledge engineering.

6. Research on Inspection of Equipment and Repair Robot Technology

Takasago Research Institute is carrying out the inspection of nuclear plants and development of repair robots, and is conducting research on practical use of these repair robots by combining advanced electronic control technology and robot technology.

7. Research on Fuel

At present, MHI is constructing a fuel hot laboratory in Tokaimura to perform PIEs (post-irradiation test) for fuel, and is making efforts to promote further the development of improved fuel used in MHI's PWRs.

8. Research on Nuclear Power Peripheral Units and Fuel Cycle Units

Takasago Research Institute is conducting overall research on systems to reduce the volume and stabilize the radioactive wastes discharged from nuclear plants. Also, it is conducting research on fuel transport vessels, and fuel reprocessing facilities and equipment, and contributes to the establishment of fuel cycles.

A part of the technical development work related mainly to PWR has been introduced up to now. At present, Takasago Research Institute is enthusiastically carrying out the development of an APWR which will be a complete compilation of these technologies, and is scheduled for completion in March 1987. In addition, it is buckling down to the development of an FBR and nuclear fusion reactor which will replace the LWR (light water reactor) as the next-generation energy source.

9. R&D of FBR

Takasago Research Institute is developing the Na system and equipment, operating technology, safety, and equipment high temperature design method in a special purpose laboratory built to develop a liquid-metal cooled fast reactor. Also, it is conducting research on design, manufacturing method, and safety of systems and such equipment as the nuclear reactor vessel and steam generator installed in the prototype nuclear reactor, "Monju." In addition, it is presently carrying out R&D of a design to rationalize demonstration reactors while making the most of technologies used in the Monju and PWRs.

10. R&D of Equipment of Nuclear Fusion Reactors

Takasago Research Institute is carrying out the development of special technologies such as cryogenic and ultrahigh vacuum technologies necessary for nuclear fusion reactors, material and joint technology, and isotope separation technology, and the development of various equipment systems such as fuel intake and exhaust systems which are part of nuclear reactors. Particularly with regard to nuclear fusion, it is cultivating basic technologies and men of talent from a long-term perspective.

III. Postscript

Up to now, I have introduced some of the research work in the Takasago Research Institute related to nuclear power. I think that readers understand the outline of the Takasago Research Institute. With regard to the nuclear power development by MHI, besides the Takasago Research Institute, the Nagasaki Research Institute and Hiroshima Research Institute are in charge of research on HTGCR (high temperature gas-cooled reactor) and the uranium development unit, respectively.

Finally, we intend to make every effort to promote nuclear power which will be advanced and diversified increasingly in the future, and intend to contribute to the development of the Japanese nuclear power industry.

Kawasaki Steel Corporation

Tokyo NIHON GENSHIRYOKU GAKKAISHI in Japanese Sep 86 pp 27-29

[Article by Yoshio Ejima, Mizushima Research Department manager and vice chief of Steel Research Laboratory of Technical Research Institute, Kawasaki Steel Corp.: "Research Institute Introduction Series 16--Technical Research Institute of Kawasaki Steel Corp."]

[Text] I. Preface

As an all-round steel manufacturer, Kawasaki Steel Corp. manufactures various kinds of steel materials. With regard to materials related to nuclear power, the company supplies thick plate, cast steel, forged steel, steel pipe, shape steel, deformed bar steel, wire rod steel, and welding material. The Technical Research Institute is the pivot in charge of R&D of these materials, and supports plants which manufacture steel materials.

II. Outline of Technical Research Institute

In 1985 the company initiated the Technical Research Institute Main Office consisting of the Steel Research Laboratory and High-Technology Research Laboratory by reorganizing technical research laboratories which had been used until that time. The Technical Research Institute was established to promote the development of new businesses and of products in chemical and new material fields as well as in the conventional steel field. Figure 1 shows an organizational chart of the Technical Research Institute. The headquarters

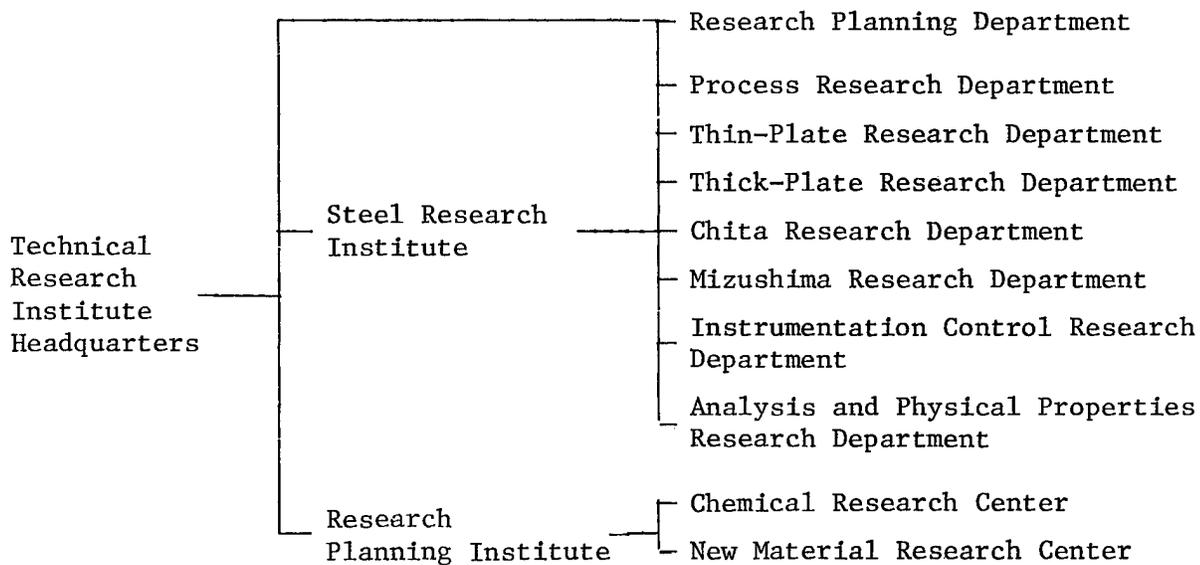


Figure 1. Organization of Technical Research Institute

(shown in Photograph 1 [omitted]) of the Steel Research Laboratory is located on a site of 57,212 m² in the Chiba Ironworks, and a research facility corresponding to each factory is located in Mizushima, Chita, and Kobe. On the other hand, the High-Technology Research Laboratory is placed side by side with the Steel Research Laboratory in Chiba. The number of staff engaged in the Technical Research Institute is 1,270 as of 1 July 1986. Table 1 shows the organization of the Technical Research Institute.

Table 1. Organization of Staff in Technical Research Institutes (as of 1 July 1986)

	Research Planning Department	Steel Research Institute				Mizu-shima	High-Technology Research Institute	Total
		Chiba	Kobe	Chita				
Business	43	-	4	3	8	-	58	
Technology	37	214	8	21	63	159	502	
Skilled occupation	538	-	31	37	104	-	710	
Total	618	214	43	61	175	159	1,270	

The Steel Research Laboratory conducts research on processes for manufacturing steel materials for nuclear power, development of materials, and evaluation of the characteristics of these materials. It has research facilities necessary to carry out research work, the most important of which are various units such as smelters and rolling mills; units for evaluating and testing characteristics such as fracture toughness, high-speed tension, fatigue, creep, and stress corrosion cracking of various materials; and various machinery and tool analysis equipment.

Photograph 2 [omitted] shows a tension tester for large structures. It can perform tension tests at a maximum load of 8,000 tons and perform fatigue tests at a maximum load of 5,000 tons. The tension tester was used to investigate the brittle fracture characteristics of a test piece (250 mm x 1 m x 1 m and weight of 2 tons) of steel plate for LWR (light water reactor) pressure vessels. Data useful for evaluating safety have been obtained.

Photograph 3 [omitted] shows tension test jigs and a cryostat for liquid He used to develop cryogenic materials.

III. R&D of Matters Related to Nuclear Power

1. Light Water Reactor

With regard to the steel material for pressure vessels, the company has developed a forged steel shell ring by using a cored steel ingot as well as a thick steel plate, and has put it to practical use. The forged steel shell ring made of cored steel ingot is superior to the conventional forged steel shell ring made of solid steel ingot in quality characteristics of internal surface, and meets users' expectations in both safety and economy.

The company has developed MAGLAY as a welding process to overlay the internal surface of pressure vessels. This process with high efficiency can overlay stainless steel bands with a maximum width of 300 mm to use in the internal surface of these pressure vessels, and produces excellent characteristics. The process has widely been put to practical use in Japan as well as foreign countries, and plays a role in enhancing the quality of pressure vessels and reducing the manufacturing cost. Photograph 4 [omitted] shows the MAGLAY overlay process.

The company independently conducts research on evaluation of various characteristics such as the brittle fracture and fatigue fracture of the steel material for these pressure vessels. Also, the company works in collaboration with the Atomic Energy Research Committee of the Japan Welding Engineering Society. Data obtained from the research are useful, and greatly contribute to the evaluation of safety.

With regard to the thick steel plate for containment vessels, the company has developed the thick-walled material and high-strength material suitable to large nuclear reactors, and has also developed the steel material which can be used in cryogenic areas. This steel material is excellent in cryogenic toughness. After these materials are evaluated through large-scale fracture toughness tests, they will be available for commercial use.

When casks for transporting spent nuclear fuel are manufactured by using forged steel, the cored steel ingot will be used. As a result, the casks possess excellent characteristics. The company has already manufactured a large number of such casks. In addition, the company has participated in the QA Research Committee of the Electric Power Central Technical Research Institute, and has been conducting R&D of ductile cast iron casks to transport and store spent nuclear fuel.

The development of next-generation machinery and tools is being carried out. The company has joined the Next-Generation Equipment Technical Research Association, and has been conducting R&D of new materials.

2. Fast Breeder Reactor

With regard to steel materials for the prototype fast breeder reactor, "Monju," the company has developed stainless steel thick plate, forged steel, and materials to weld them. With regard to steel materials for demonstration reactors, the company conducts research on consignment from the PNC (Power Reactor and Nuclear Fuel Development Corp.), and has carried out the development of SUS 304 steel and the improved version of 9Cr-1Mo steel, and materials to weld them. Also, the company is conducting R&D of double wall tube (material: improved version of 9Cr-1Mo steel) for the PNC for application to a new type steam generator for FBRs (fast breeder reactor). In addition, the company is actively carrying out, in collaboration with the Japan Welding Engineering Society, the development of 9 percent Cr-Mo steel as a steel material for steam generators.

3. High-Temperature Gas-Cooled Reactor

The company and the JAERI (Japan Atomic Energy Research Institute) are jointly conducting investigation and research on characteristics such as neutron irradiation embrittlement when the 2-1/4 Cr-1Mo forged steel is used as a steel material for HTGCRs (high-temperature gas-cooled reactor), and are accumulating data on results obtained from the investigation and research.

4. Nuclear Fusion Reactor

Various foreign countries as well as Japan are developing the nuclear fusion reactor as a new primary energy source. The following can be cited as structural materials: 1) first wall blanket reactor core material; 2) cryogenic material for superconductive magnets; and 3) nonmagnetic support material.

With regard to item one, the company has participated in the development of the Ti-added 316-system stainless steel and welding materials as a part of the joint research being led by the JAERI, and is conducting investigation and research on high temperature tension and fatigue characteristics of this stainless steel and these welding materials.

With regard to item two, the company has been carrying out the development of cryogenic materials with high strength and high toughness under a joint research contract with the JAERI, and has developed new alloys based on the

Ni-Cr system and the Mn-Cr system as candidates for support structural materials for superconductive (poloidal) and toroidal coils. These new alloys are much superior to conventional materials in strength and toughness at liquid He temperatures.

With regard to item three, the company is conducting research on modification of high Mn nonmagnetic steel which has actually been used in the JT-60 (JAERI Tokamak-60).

IV. Conclusion

The Technical Research Institute of Kawasaki Steel Corp. will develop and supply products with the characteristics, high quality, and high reliability which are required in nuclear materials; will continuously carry out research work with the aim of supplying various materials extending from conventional steel materials for LWRs (light water reactors) to new materials and new steel materials for nuclear fusion reactors; will meet the demands of users; and wants to contribute to the development of the nuclear industry.

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NEW NE6(T), FE6 DIESEL ENGINES DEVELOPED FOR U.S. MARKET

Tokyo NAINEN KIKAN in Japanese Jan 87 pp 68-74

[Text] 1. Introduction

Nissan Diesel Motor Co., Ltd., has introduced four different truck models of the middle weight class (GVW 8 to 15 tons) into the U.S. market. There are two models (CPB12, CPC12) for class 7, one model (CLA83) for class 6, and one model (CMA83) for class 5. The new engines, the new NE6(T) model diesel engine and the FE6 model diesel engine, accommodate the U.S. market and regulations. They are direct injection diesel engines of 160 to 210 HP with low fuel consumption and high reliability.

In the development of these engines, several market surveys, road tests in the United States, and users' tests on sample vehicles were repeated, and also an on-the-spot investigation of road conditions, climate conditions, and the actual conditions of truck use were conducted.

The actual conditions for the classes 5 to 7 can be approximately summarized as follows:

- (1) Most cases are for transportation between neighboring cities. The average running distance per day is about 200 to 300 miles.
- (2) Connecting highways between cities have 1 to 3 percent grade level.
- (3) Excessive loading is not often seen. Small vans are common.
- (4) Cruising speed is about 55 to 65 mph. There are infrequent traffic jams in city driving except in metropolitan areas. Cruising speed in city driving is about 40 mph.
- (5) Standard climate is 0 to 110°F.
- (6) Roads can go to 11,000 feet above sea level.

Based upon the above investigations these new engines, i.e., the new NE6(T) model and the FE6 model, were put on the U.S. market with confidence. They have been favorably received. The outline of these engines follows.

2. Purpose of Development

The purpose of the development of the new NE6(T) model and the FE6 model engines for the U.S. market were set as follows:

(1) To meet the various regulations and standards, such as the exhaust gas standards (Federal and California), the smoke standards, the noise regulations, and the federal motor vehicle safety standards.

(2) To achieve a high power and low fuel consumption engine.

The study of running modes in the United States indicated that running frequency at high speed is high. This encourages development of an engine which shows its superiority in power performance and fuel economy at high speed.

(3) To improve durability and reliability

Based upon the quality of the NE6 model and the FE6 model engines which have an excellent reputation in domestic and overseas markets, their overhaul life, inspection and serviceability, and durability and reliability must be improved.

(4) To set up specifications which comply with the actual conditions of the U.S. market.

The specifications should be the results of thoughtful consideration on specific climate conditions, geographical conditions, fuel, water quality conditions, and local customs.

3. Main Specifications and Performance

Table 1 lists the main specifications of the new NE6(T) model and the FE6 model engines. Their performance curves are shown in Figures 1 to 3.

Table 1. Main Engine Specifications

() denotes California specification

Item	Engine model	NE6	NE6(T)	FE6
Number of cylinders and arrangement		Straight 6-cylinder Longitudinal	←	←
Configuration of combustion chamber		Direct injection	←	←
Total displacement (in ³)		452	←	423
Bore x stroke (in)		4.333 x 5.118	←	4.252 x 4.961
Compression ratio		18	17.5	18
Maximum power (HP/rpm)		175/2800	210/2800 (200/2800)	170/3000 (160/3000)
Maximum torque (ft lbs/rpm)		376/1400	470/2800 (456/1600)	332/1600
Minimum fuel consumption rate at maximum load (lbs/HPh)		0.357 x 1400	0.346/1600 (0.351/1400)	0.353/1600 (0.358/1600)

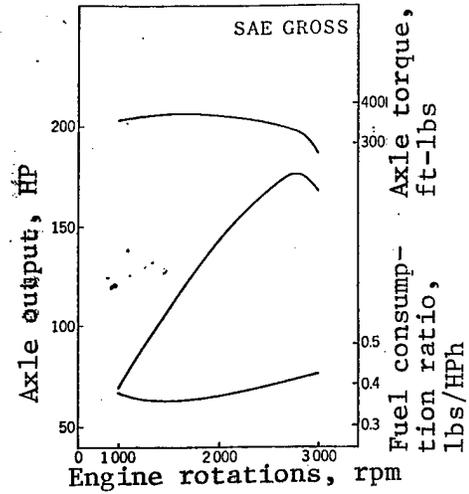


Figure 1. NE6 Model Engine Performance Curves

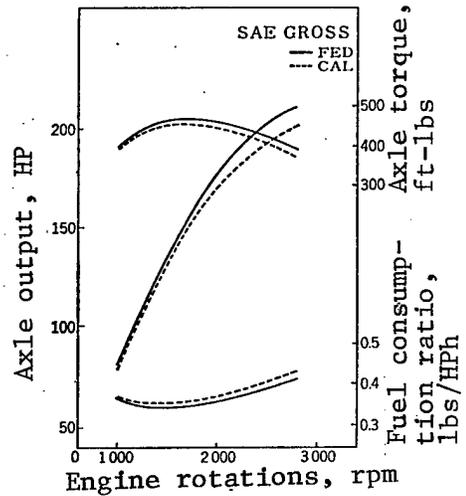


Figure 2. NE6(T) Engine Performance Curves

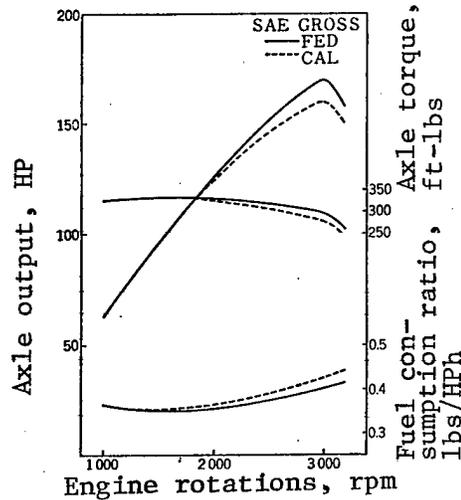


Figure 3. FE6 Model Engine Performance Curves

4. Progress of Development and Features of Engines

(1) Conformity With Regulations

Various kinds of regulations in the United States have been continuously strengthened. It is necessary to match the NE6(T) model and the FE6 model with the various regulations listed in Table 2. Developmental progress on the conformity of exhaust gas standards as distinguished from American specific testing methods is discussed.

Table 2. Exhaust Gas Standards Applied to These Engines (to '87 MY)

Standards		Regulation values () indicates for California
Exhaust gas (g/HPh)	HC	1.3
	NO _x	10.7 (5.1)
	CO	15.5
Smoke (percent)		20
		15
		50
Blow-by gas		No discharge into the air
Useful life		185,000 miles or 8 years
Maintenance standards		Cleaning of nozzle tip and PCV valve. Replace after every 50,000 miles.
High altitude adjustments		Regulations for necessary engine adjustment methods when used at 4,000 feet or over above the sea level.

① Exhaust gas certification facilities

Figure 4 shows the outline of our bench test facilities for exhaust gas measurement. The operating device has the capability of the automatic measurement of the U.S. exhaust gas certification transient mode with the application of computer control. In addition, there is the capability for operations in various modes. The exhaust gas analysis device is the CVS method with a large size dilution tunnel. The measurement of particulates which will become the new standards from 1988 is also possible.

② Conformity of exhaust gas standards

Figure 5 shows a loading frequency distribution under a transient mode, and Figure 6 shows an exhaust weight distribution of an exhaust gas component (NO_x). These figures are plotted on the coordinates plane of the number of engine rotations vs. loading.

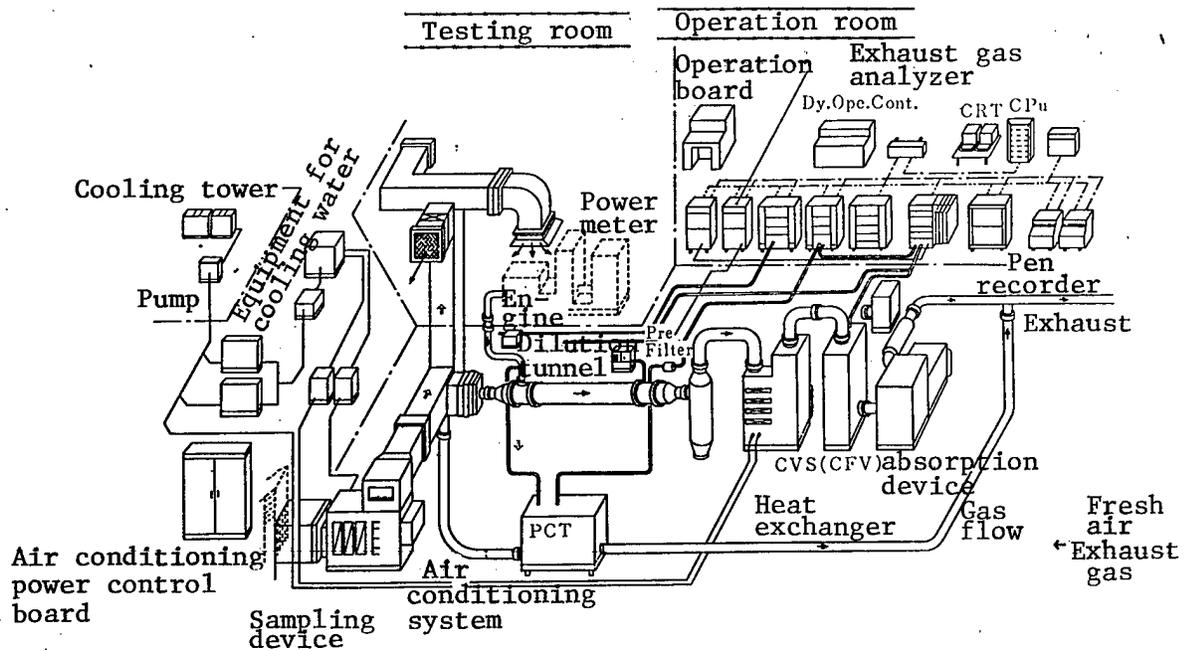


Figure 4. Exhaust Gas Measurement Device

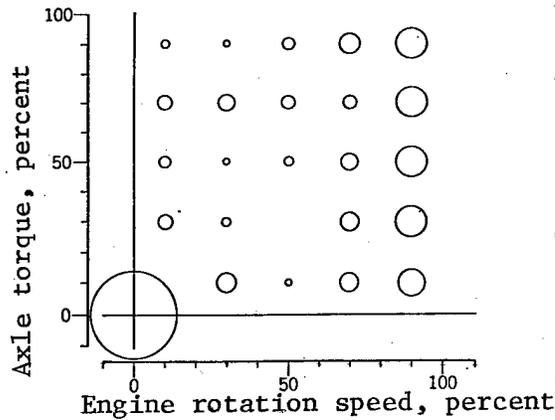


Figure 5. Loading Frequency Distribution Under Transient Mode (Time Ratio)

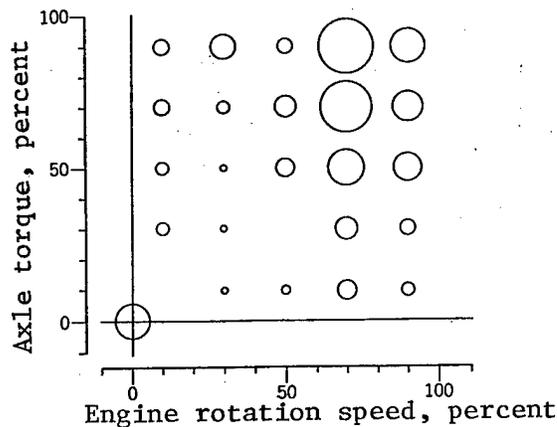


Figure 6. Exhaust Gas Weight Distribution Under Transient Mode (NO_x)

Figures 5 and 6 show the American transient mode used mainly for a high-speed range. In order to conform to the standards, the reduction of an exhaust gas concentration in a high-speed range is effective.

There is the trade off between HC and NO_x under a parameter of injection timing. It is well known that degradation in performance such as power and fuel economy is caused by timing retard (Figure 7). Judging by this viewpoint, on the basis of the combination of a low swirl head with a high injection efficiency pump, the improvement of power and the reduction of exhaust gas were designed by the optimum matching of a piston compression ratio, cavity configuration, and nozzle.

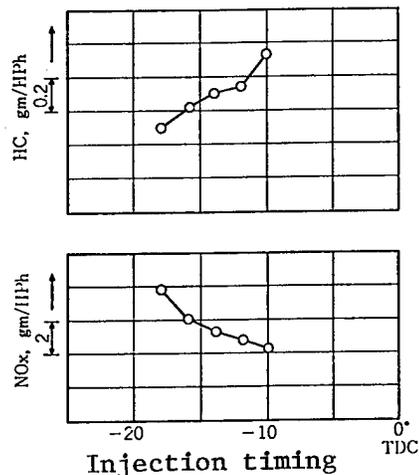


Figure 7. Injection Timing and Exhaust Gas

In the next, injection timing which permits NO_x was set up. Various kinds of tests to recover HC which was expelled due to timing retard were carried out. As a result, the recovery of HC was achieved by a reduction in the suck volume of a nozzle tip (Figures 8 and 9). Since the California regulation requires a large reduction in the amount of NO_x discharged, and enforces a large amount of timing retard, the aggravation of HC exhaust will be seen. A seat hole nozzle has been recognized as an effective measure to reduce the amount of HC. However, there is an injection hole in the seat portion. This causes a larger flame contact area at the top of a nozzle tip, and also increases the temperature around the seat portion and frictional force. To solve the above problems associated with heat, the improvement of cooling performance around the nozzle holder attachment portion of a cylinder head and the proper modification of the injection system were applied. Figure 10 shows the results of temperature measurement of the seat portion.

Moreover, transient mode gas simulation was tried by a steady mode gas map. That is, the amount of exhaust gas in an instant at the steady mode exhaust gas map is assumed to be the same amount as that of exhaust gas under the same operating conditions. By carrying out iterative calculation for the whole mode, the amount of transient mode exhaust gas is obtained. The results are

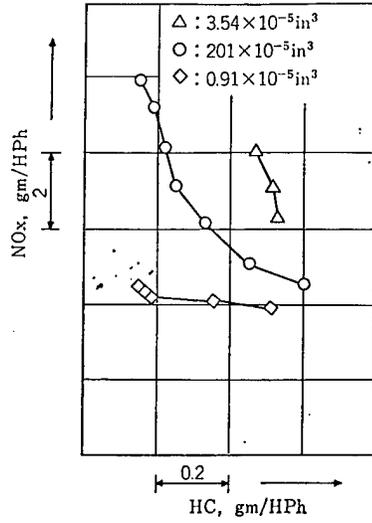


Figure 8. Nozzle Suck Volume and Exhaust Gas

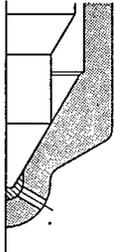
Types	(Mini-mass) nozzle	Seat hole nozzle
Applicable engine models	NE6 NE6T FE6(federal)	FE6(California)
Shape		
Suck volume	$2.01 \times 10^{-5} \text{ in}^3$	$0.915 \times 10^{-5} \text{ in}^3$

Figure 9. Configuration of Nozzle

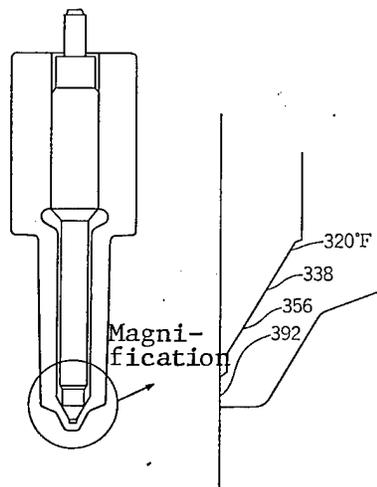


Figure 10. Temperature Distribution Around Seat Hole Nozzle

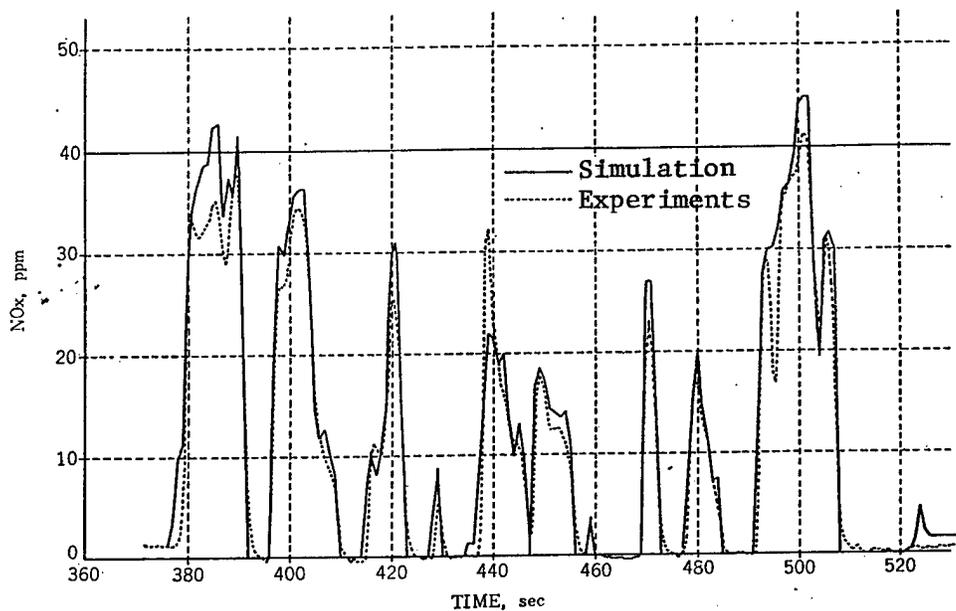


Figure 11. Transient Mode Simulation (NO_x)

indicated in Figure 11. Regarding NO_x , a relatively good correlation was seen, and the advancement of development was achieved.

(2) High Power and Low Fuel Consumption

In accordance with a market survey and the distribution of usage frequency obtained through users' tests, the appropriate modification of a piston compression ratio, cavity configuration, the number of injection holes of a nozzle, the diameter of injection holes, and an injection hole angle were studied based upon the combination of a low swirl head and a high injection efficiency pump in order to improve combustion in a high-speed range frequently in use.

In addition, in order to improve volume efficiency and to reduce pumping loss, the enlargement of an intake/exhaust port cross sectional area and the diameter of a valve, and the increase of the amount of valve lift were carried out. As the result, as shown in Figure 12, it was possible to improve drastically fuel economy in a high-speed range.

5. Durability and Reliability

Regarding the development of engines for the U.S. market, we assembled technologies which had been accumulating over a long time. At the same time, we very carefully considered climate, geographical, and regulatory conditions peculiar to the U.S. market. Frequency of long distance driving in the United States is higher than in Japan. On an average, a customer in the United States uses a vehicle longer. Our efforts to wrestle with a problem associated with durability and reliability of the engines will be mentioned.

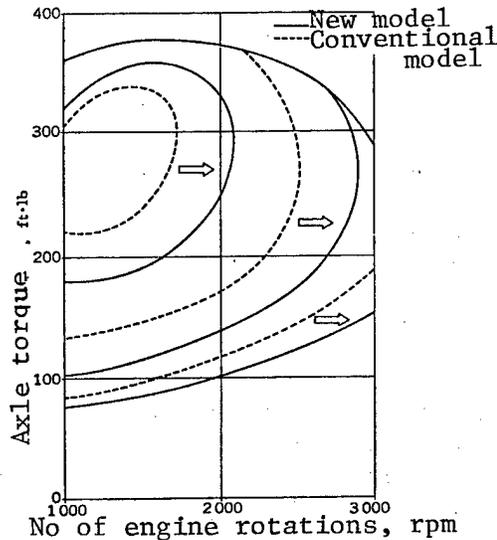


Figure 12. Improvement of Fuel Consumption at High Speed

(1) Overhaul Lifetime

In order to minimize friction exerted on a moving portion which has great influence on overhaul lifetime, various considerations on designing were given. Principal considerations are as follows:

① A thin piston ring was adopted because of its stability at high speed. On rubbing contact surface with a liner, hard chrome plating was applied. An oil ring is extremely soft; a steel oil ring shows a capability to follow the shape of a bore (Figure 13).

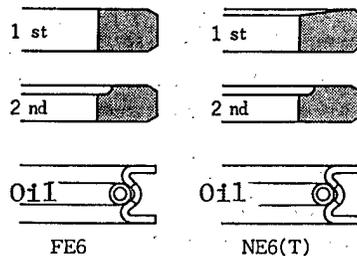


Figure 13. Piston Ring Configuration

② In order to reduce friction of bearing metal, a bearing load was reduced as low as possible. Highest-grade three-layer structure metal with indium plating was adopted as the metal material.

③ A valve seat and valve guide are made by sintering alloy. This gives better abrasion-resisting characteristics than that of conventional steel-made ones (Figure 14). An engine valve is made by heat-resisting alloy.

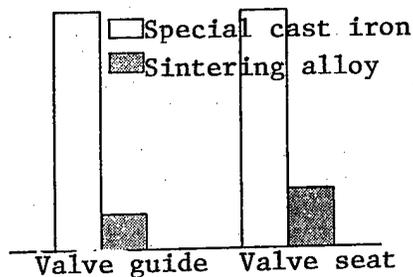


Figure 14. Comparison of Friction for Valve Guide and Seat

The (tufftride) method is applied to this part for the purpose of an improvement in abrasion resistance and corrosion resistance. Stellite is applied to the surface of the seat of an exhaust valve. This brings excellent abrasion resistance under high temperature.

(2) Serviceability

In order to reduce the users' daily inspection load as much as possible, various kinds of designing considerations were implemented.

- ① Regarding a V-belt, the simple three-axis driven system was used because of its ease of decomposition/assembly and inspection/service.
- ② In order to minimize a change in valve clearance, the sintering alloy valve seat was adopted as described before. In addition, steel laminate material was applied to a head gasket. This drastically improved the amount of variation in clamping thickness compared to the conventional one. As a result, valve clearance adjustment at every 30,000 miles is very comfortable.
- ③ Oil, fuel, and intake air filters for exportable vehicles were looked at again. An interval of filter exchange was decided to be extended. Oil and fuel filters are the (spin-on) type cartridge filters. A screw portion matches the U.S. standards. Regarding an air filter, the (Donaldson) standard one is in use. It makes it easy to exchange a filter on-the-spot.
- ④ In addition to the above, a cooling water level sensor with a warning lamp installed on an oil level gauge and dashboard--those can be inspected without raising the cab--and a sedimenter which indicates a water level in accordance with the circumstances of fuel in the U.S. market are standard equipment (Figure 15).

(4) Market Conformity

On the huge American continent, there are the unique and distinguished environmental circumstances and market conditions which are different from those in Japan and other general exporting countries.

① In the first place, it should be pointed out that voltage of electric parts used for the vehicles of these classes is 12-volt in the United States, but 24-volt in most other areas. In order to secure easy starting of an engine at cold temperature, a starter, a generator, and an intake heater with large electric capacity under the 12-volt system were newly developed, and made to conform to the U.S. market.

② Also, there are severe weather conditions ranging from more than 110°F in the summer to less than -30°F in the winter. Therefore, our efforts to achieve the specifications which satisfied cooling performance with large capacity and excellent easy starting were made. At the same time, reconsideration on the grade of rubber materials and oils and fat materials took place. This is not popular in Japan, but in the United States a block heater as a supplementary starting device at cold temperature is commonly in use. In order to use various block heaters available in the U.S. market in these vehicles, the modification of the cylinder block was carried out.

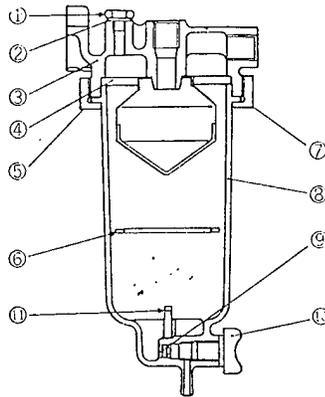


Figure 15. Sedimenter

- | | | |
|------|------------|------------------------------|
| Key: | 1. Plug | 6. Float |
| | 2. Packing | 7. O-ring |
| | 3. Cover | 8. Body |
| | 4. Screen | 9. O-ring |
| | 5. Nut | 10. Drain cock |
| | | 11. Water level alarm sensor |

③ Under cold temperature, a massive amount of rock salt and sand are scattered on a road. Rustproofing is a very important consideration for both body and engine. As a countermeasure for rustproofing, three-layer plating and cation painting were applied to a fuel tube, a fuel feeding tube, piping, and an oil pan. A stainless spring was adopted for an injection pump control lever return spring.

④ The cetane number of fuel being in use in the United States is 45, a low figure. There are about 110 cities 4,000 feet or more above sea level. A countermeasure for high grounds is inevitable. Compression ratios of the

engines for the U.S. market were determined to be 18 for the NA engine and 17.5 for the TC engine. They are designed to prevent a delay in injection timing at high ground levels.

⑤ Since the amount of water content in fuel is large, a sedimenter with large capacity was adopted. In some areas, because the quality of water used for engine cooling is detrimental, use of a water filter can prevent a rusting water pathway. Accordingly, the water filter of the ion exchange plastics type is prepared as a special option.

6. Conclusion

The outline of the new NE6(T) model engine and the FE6 model engine were described before. These engines are the result of our accumulated technologies and studies. The quality of the initial developmental targets was achieved. We believe that these engines will participate actively in the market. Since a program to strengthen exhaust gas regulations and noise standards is scheduled, we intend to study the methods to improve an engine in terms of more ease of use and higher reliability.

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DEVELOPMENTS IN CAR ELECTRONICS AT TOYOTA REVIEWED

Tokyo TOSHI KEIZAI in Japanese March 87 pp 100-102

[Text] "At present, we don't have the means for connections with the outside so that the scope of use is narrow, but shortly drivers will be able to obtain freely a wide range of desired data from independent sources." Toyota Motor Corp's Vice Chairman Kiyoshi Matsumoto thus indicated the future trend of car electronics when, two years ago, Soara's built-in electro multi-vision system, Toyota Motor Corp's first new media system, attracted public attention.

This multi-vision data system was a new data system developed with both driver and passenger communication in mind. When the car is in motion, a CRT display (Picture Tube) installed on the center console will display data which has a function in driving. When the car is stopped various types of data such as TV broadcast reception can be displayed in multiple mode in the limited visual space.

At present, reception of data by this new system from external sources is limited.

Excepting television and radio waves, CB radios and car telephone have just attained popularity, and application possibilities are still things of the future. Once point of contact technology is developed, it will be possible to link an upgraded multi-vision system to CAPTAIN system (Character And Pattern Telephone Access Info Network) so that the dream of a new media car will grow with possibilities such as receiving facsimile via the car telephone.

Matsumoto also stated "If this dream is realized, it will be technologically possible, for example, to receive a map by facsimile if one loses his way, or to perform data processing and computation tasks through a small computer installed in the car, and to obtain information by data communication links with external sources." In this manner, the movement toward car electronics is a response to the information age and is proceeding with a new concept of the "moving office."

The basic goal of car electronics is the creation of a man-machine system which will link the car to people. It is composed of three elements: sensors,

computers and actuators. The function of this structure is to create a feedback control loop between the driver and vehicle. Sensors will pick up data from external sources, the condition of the vehicle and driver instructions.

These data converted to digital form will be processed by a computer. The data would then be passed along the communication path to the actuators which would execute the necessary controls. In other words, it will serve to assist the controls executed by the car and driver.

At Toyota Motor Corp, there are two trends in the car electronics movement for which research and development are in progress. The two trends are the upgrading of vehicle performance and the creation of moving space.

If we look at Toyota Motor Corp's record to date in the area of car electronics, we see that heavy emphasis has been placed on improving car performance. The method was to raise the level of control of the three main components of the car, the engine, transmission and steering, through the use of electronics systems.

Although performance improvement is easy enough to say, there are many annoying problems involved. For example, one cannot improve physical performance factors such as engine output and speed by simply using electronics technology. If we look at running motion, one of the three basic principles of the car, which also include turning and stopping, we can see that there are many control conditions which exist on a higher dimension such as a sure engine start, vehicle acceleration and free speed control, fuel efficiency, and clean exhaust. There are many opposing conditions also, the resolution of which determines whether performance can be improved.

The struggle in car electronics, until now, has been tackled from this point of view.

The most important factor in driving performance is, needless to say, engine control technology. The development of car electronics technology at Toyota Motor Corp made its start from this field.

Toyota Motor Corp's work in the car electronics field dates back to the late 1950s beginning with the transistor radio and practical applications of the silicon diode for AC current generation. The electric overdrive mechanism of the early Toyota Crown (RS-10 series) is the starting point. The importance of car electronics was recognized by Toyota Motor Corp at this time and led it early on to form its development structure. In late 1960s, the fruits of their effort appeared with the development of a semitransistor ignition system and a transistor type fuel pump. Moreover, with electronic autodrive and electronically controlled auto drive, electronics technology began its move to include the chassis area also.

However, it was only in the early 1970s that the car electronics age came into its own. With the development of the semiconductor and its

applications, Toyota Motor Corp's research into electronics quickly moved forward. Research into applications technology yielded the development of a comprehensive control system - TCCS (Toyota Computer Control System). This system is a high level semiconductor application technology which controls fuel injection, ignition timing and idling rpm.

Having gained confidence with the establishment of engine control technology, the development of control systems spread from the engine to transmission and traction studies. The world's first microcomputer controlled automatic speed change mechanism (ECT) and an electronically controlled suspension (TEMS) were the results of this development.

During the latter part of the 1970s, the strategy in car electronics included, of course, raising systemization of engine control to an even higher level, and also began to include the chassis and motion areas of study in order to improve comfort of the ride.

The first application was the auto-drive mechanism or automatic speed control device, whereby a driver can set a desired speed and can maintain that fixed speed without having to depress the accelerator or brake pedals. Moreover, other advances in technology are being developed one after the other. These include four-wheel ESC to control wheel lock, spring constants, attenuation, electronically controlled suspension which changes the height of the car depending on the road conditions, and PPS (vehicle speed response power steering) which electronically controls the heaviness of the steering depending on speed.

The fact that the Japanese have outstripped European and American passenger cars with tremendous force and have assumed the leading position in the world-wide automotive industry is due in large part to the state-of-the-art car electronics technology.

Toyota Motor Corp, predicting an increase in demand for car electronics, strengthened its corporate development structure in February of 1985. As seen in the organizational chart below, the Toyota Research Labs, Toyota Group and the Higashi Fuji Labs function efficiently around the Electronics Technology Division, its nucleus.

Until this organization was established the electronics research organs were scattered among all the divisions while Nippon Denso Co., Ltd. handled much of the development.

"It's not that we did not handle the research and development within our company. On the contrary, we were very much involved. At the time measures were being taken to solve the problem of exhaust gas, our company was in fact the one that took the initiative with our decision that in order to meet specifications, it was necessary to have precise control using electronics technology."

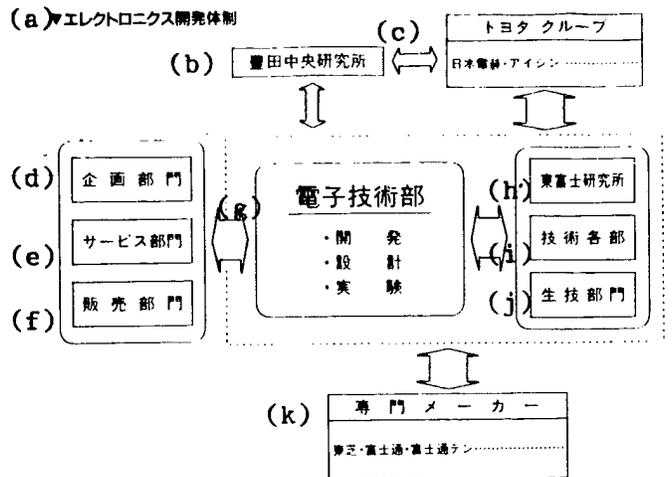
Akio Numasawa, managing director and head of the electronics technology division, further explained the reason for the new facilities in saying, "As electronics technology was upgraded and as it became more complex, applications to vehicle comfort, safety and energy efficiency suddenly began sprouting. To meet this trend, we had to reorganize our entire electronics staff to create an efficient R&D system."

There are over 400 persons working for the electronics technology division. About 200 of them are engineers from various groups such as equipment, control, driving and traction departments of the first technology division. In other words, engineers from all sections who have been involved in electronics research have been brought together.

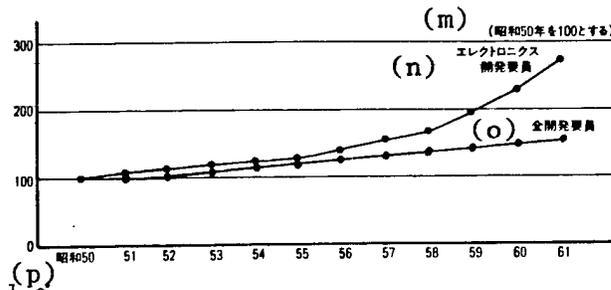
Here the main work of research and development centers around electronics related planning, design, evaluation and testing. The key to keeping pace with the rapidly improving electronics system is the setting up of an organizational structure for planning.

Last February (1986) an electronics manufacturing division (staff of 150 persons) was newly established. While it will work in concert with the electronics technology division, a proposal to incorporate it partially in this division has been worked out.

In the last few years, the number of persons working in the development of electronics related fields has increased conspicuously because of this R&D reorganization. The graph below shows an upward trend in personnel hiring for both total R&D personnel and electronics development personnel. As seen from the figure, the upward curve got steeper about 1982 and 1983.



(1) ▼開発要員の推移



[Key on following page]

- (a) Electronics R&D System
- (b) Toyota Central Research Laboratory
- (c) Toyota Group
Nippon Denso, Aishin, etc.
- (d) Planning Department
- (e) Service Department
- (f) Sales Department
- (g) Electronic Technology Division
R&D
Design
Testing
- (h) Higashifuji Research Laboratory
- (i) Technical Divisions
- (j) Production Technology Department
- (k) Specialized Manufacturers
Toshiba Corp.
Fujitsu, Ltd.
Fujitsu Ten
- (l) Trend in R&D Personnel
- (m) Number in 1975 is taken as 100
- (n) Electronics R&D Personnel
- (o) Overall R&D Personnel
- (p) 1975, 1976, 1977, 1978, 1979, 1980, 1981,
1982, 1983, 1984, 1985, 1986

The electronics field far outstrips the pace of increase for total R&D personnel growth. This growth indicates directly the extreme importance Toyota places on this field.

Research and development investment was 4 percent of sales, that is, 250 billion yen per annum; and the proportion of these funds allocated to the area of electronics grows yearly.

Car electronics research and development until now, has been concerned with drivability, that is, riding comfort, safety, and energy conservation, but is now expanding into areas such as new media communications technology in order to provide a luxurious moving environment.

The experimental FXV shown at the 26th Tokyo Motor Show demonstrates these trends. Take, for example, the engine and drive control systems. The FXV incorporates R&D technology for a total control system including a complex supercharging system which is a combination of super-charger and turbo-charger, a partial lean burn system, and five speed automatic transmission. Fuel economy and compression are contradictory requirements which electronics technology tries to reconcile at a high level. Further, as far as chassis and driving control technology are concerned, technology development is steadily progressing in every type of suspension control and four-wheel drive control. Another system included in the FXV which must be noted is the hydro-pneumatic suspension system - a system which electronically controls absorber attenuation, spring constants and vehicle height.

For these systems, total control is indispensable and it is for this reason that Toyota Motor Corp is handling the project by consolidating its technology division forces. Looking ahead, another goal is the realization of a system which will use electro-magnetic wave and laser technology to warn the driver if he is too close to another vehicle and will automatically make the necessary adjustments.

As mentioned earlier, another important field is the development of a system which will meet the needs of the information age. The test model FXV has been built with a comprehensive information system (multi-information system) and is thus a harbinger of future trends.

The development of many new systems is anticipated as the importance of driver-vehicle communication increases. If this information system is linked to compact disks and car telephones, it will be possible to have any type of data displayed. The air conditioner, audio system and telephone can be operated by a touch switch located on the display screen. If the car phone is connected to the CAPTAIN service, that data, of course can also be displayed on the screen. If this is done, the result will be a moving media room. These projects still belong to the future in electronics strategies, but Toyota Motor Corp's technology is advancing toward these goals one by one.

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END