The Dean IAT and the members

of

Institution of Armament Technologists (India)

request the pleasure of the company of

Dr B S Madhava Rao

at Dinner at the Officers' Mess

on Friday the 21st June 1974 at 8 pm

RSVP

PMC

Date 23.6.74

No 001124

OFFICERS' MESS I. A. T.

POONA 25.

Received from Dr Madhava Rao

Rupees Fifty three and paise fifty only

on account of Mess bill for Jun 74

by Cash/Cheque No. cash on 23.6.74

Mess Bill Rs. 53=50

Credit Rs. -

Net Amount Rs. 53=50

Treasurer

INSTITUTE OF ARMAMENT TECHNOLOGY, GIRINAGAR

NON-LINEAR BALLISTICS SEMINAR

DETAILS OF

INAUGURAL SESSION

Chairman : Prof BS MADHAVA RAO

0930 - 0940	Welcome by Dr JN NANDA Director and Dean IAT.
0940 - 0955	Inaugural Address by Vice Admiral VA KAMATH, PVSM, Vice Chief of Naval Staff.
0955 - 1020	Technical Address by Prof PC RATH.
1020 - 1035	Address by the Chairman.
1035 - 1040	Thanks by Capt GC MITRA, IN
1040	Tea.

0034

I A T OFFICER'S MESS. GIRINAGAR, PUNE - 23

DAILY SUMMARY OF ACCOUNT

RANK NAME B.S. MADHAVA RAO STAFF / COURSE NO MONTH June 74 19 MESS BILL

DATE	DAILY MESSING Rs	P	EXTRA MESSING DETAILS	AMOUNT Rs	P	WINES SPIRITS & BEER Rs	P	TOBACCO MINERALS & SUNDRIES Rs	P	PARTY ACCOUNTS DETAILS	MESSING RS.	P	BAR Rs	P
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PARTICULARS	Rs
MESS SUBSCRIPTION	
MESS MAINTENANCE	
ENTERTAINMENT	
LIBRARY	
GARDEN	
LADIES CLUB	
OFFICERS' INSTITUTE	
GENERAL ADVANCE	
INSTALMENT V.I.P.	53-50
DAILY MESSING	~~17-00~~
EXTRA MESSING	
MESS SERVICE	
PARTY CHARGES (MESSING)	
PARTY CHARGES (BAR)	
WINE BULK CHITS ( )	
STORES RETAIL CHITS ( )	
RSI SUBSCRIPTION	
RSI BILLS	
ADM RECOVERIES	
SILVER FUND	
DRAPERY CHARGES	
ROOM BEARER CHARGES	
SERVANTS QUARTERS	
FURNITURE	
MISCELLANEOUS	
DHOBY CHARGES	
BAND	
TOTAL BILL	53-50 ~~17-00~~
LAST MONTH'S CREDIT / DEBIT	
BRIDGE DEBIT / CREDIT	
TOTAL CREDIT / DEBIT	
MESS SERVANTS GRATUITY	53-50
GRAND TOTAL	~~17-00~~

53-50

DATE 22.6.74 MESS SECRETARY

MESS BILL IS TO BE SETTLED BY THE 15 TH OF THE MONTH. CHEQUES ARE TO BE MADE IN FAVOUR OF 'OFFICERS' MESS IAT - Re 1/- IS TO BE ADDED AS BANK COMMISSION FOR OUTSTATION CHEQUES

2. THIS BILL UNDER ALL CIRCUMSTANCES IS TO BE PAID IN FULL WITHOUT DELAY, BUT, IF ANY OVER-CHARGE IS POINTED OUT THE AMOUNT DUE, IF AGREED TO WILL BE REFUNDED.

RECEIVED Rs. . . . . CASH/CHEQUE NO

DATE . . . . . MESS SECRETARY

Please complete the following and submit to Receptionist.

Name, .

Date and Time of Arrival

Date and Time of Departure

Whether Detention Certificate required. Yes/No.

Whether presenting research paper/
delivering a lecture Yes/No.

INSTITUTE OF ARMAMENT TECHNOLOGY, GIRINAGAR, PUNE-25

ADMINISTRATIVE ARRANGEMENTS

FOR

DELEGATES ATTENDING NONLINEAR BALLISTICS SEMINAR JUNE 74

1. Mess Timings

Break Fast	0730-0830
Lunch	1300-1430
Dinner	2000-2200

2. Conveyance to Delegates

A) Officers Mess to Technical area and back.

21 June 74

0830	Officers Mess to IAT
1300	IAT to Officers Mess.
1445	Officers Mess to IAT
1800	IAT to Officers Mess

22 June 74

0815	Officers Mess to IAT
1320	IAT to Officers Mess
1445	Officers Mess to IAT
1830	IAT to Officers Mess

B) Return journey to Railway Station

~~0600 & 1430~~ 0600 & 1430 hrs on 23 June 74.

C) Poona Municipal Transport (Route No 49)

From VISHRAMBAGHWADA - SWARGATE - to IAT

0530	0825	1120	1420	1715	2010
0555	0850	1145	1445	1740	2035
0620	0915	1210	1510	1805	2100
0645	0940	1235	1535	1830	2125
0710	1005	1300	1600	1855	
0735	1030	1325	1625	1920	
0800	1055	1350	1650	1945	

From IAT to VISHRAMBAGHWADA

After half an hour of the corresponding Vishrambaghwada timings.

3. Mess bill is to be paid at Officers Mess by cheque/cash before departure. The bills will be presented to the delegates on demand immediately.

4. Please ensure from the reception counter your arrangement for the return journey to Railway Station.

5. Delegates who have earlier remitted money for return journey Railway/Air reservations are requested to, immediately, contact the reservation counter or Shri ML KAPOOR, for details.

6. For enquiries during off duty hours, ring up Shri ML KAPOOR (272) OR Shri BR SAGAR (218).

INSTITUTE OF ARMAMENT TECHNOLOGY, GIRINAGAR, PUNE-25

NONLINEAR BALLISTICS SEMINAR

TECHNICAL INSTRUCTIONS

1. The location of inaugural and technical sessions is as follows -

21 June 74		
0930	Inauguration	Auditorium
1115	Invited talk	Auditorium
1500	Invited talk	Lecture Hall No 1 Ground floor Block No 4
1615	Technical session	- do -
22 June 74		
0830	Invited talk	- do -
0915	(a) Technical Session	- do -
	(b) Technical Session	Lecture Hall No 9 Ground floor Block No 1
1130 - 1315	Invited talk and Technical Session	Lecture hall No 1
1500 - 1830	Invited talk Technical session Summary	- do -

2. A visit to few of the Wings/Faculties of IAT has been arranged between 1215-1300 hrs on 21 Jun 74. Delegates are requested to assemble outside the auditorium. The Liasion Officers will be present at the main entrance of the auditorium.

..2

3. Delegates who have not submitted the papers are requested to hand over the same immediately after the session to the Chairman or Dr KC Sharma.

4. All delegates are requested to announce their names before asking question(s) to the author presenting the paper.

5. The participants are requested to submit the question(s) on the questionarie supplied to them to the Chairman of the respective sessions at the conclusion of the session.

6. Tea will be served in the Cafetaria located at first floor Block No 3 at all times.

Telephone 56454/252
Telegrams ARMINST(E)

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE
DEFENCE RESEARCH AND DEV ORGN
INSTITUTE OF ARMAMENT TECHNOLOGY
GIRINAGAR, PUNE-411025

No 4119/AM

Date

To

Dear Sir,

We have decided to organise a two days seminar on Nonlinear Ballistics on 21st and 22nd June 74. The main fields to be covered are

a) Burning of propellants
b) Stability
c) Astroballistics and related problems
d) Mathematical methods.

I shall be grateful if you could kindly accept to conduct one of the technical sessions as Chairman and attend the seminar.

With regards.

(PC RATH)
Secretary
and Chairman of Faculty of App.Maths.
I.A.T. Pune-411025

Dear Prof. Rath,

Ref. your letter No. 4119/AM dated ....

Many thanks for your kind letter with enclosures. As it happens, I am not at present attached to any Govt. Institution, and hence there is no possibility of my being deputed to attend the ~~Conference~~ Seminar ~~ms~~ on non-linear Ballistics. Further, I am unable to meet, on my own, the expenses involved. It is with much regret therefore that I have to intimate to you my inability to take part in the function.

With kind regards,

Yours sincerely
B. S. M[illegible]

Sent this today BSM
9/4/74

INSTITUTE OF ARMAMENT TECHNOLOGY
GIRINAGAR, PUNE 411025

TWO DAYS SEMINAR
ON
NON LINEAR BALLISTICS
1974

REGISTRATION OF DELEGATES

Name

Institute

Postal address

Date of arrival

(You are requested to intimate the train timings of your arrival at PUNE Station by 15 June 74)

Whether attending alone or with wife.

Registration fee remitted by crossed cheque/IPO/MO.

Please write its No and date.

Whether availing lodging and boarding facilities at IAT Officers' Mess ..... Yes/No.

INSTITUTE OF ARMAMENT TECHNOLOGY
GIRINAGAR, PUNE-411025

TWO DAYS-SEMINAR ON NON-LINEAR BALLISTICS, 1974

Title of the paper

Author

Address

ABSTRACT

Please sent to

Dr.KC SHARMA, Asst. Prof.
Institute of Armament Technology, Girinagar, Pune-411025.

INSTITUTE OF ARMAMENT TECHNOLOGY
GIRINAGAR, PUNE-411025

INFORMATION FOR DELEGATES

Location

This Institute is situated at the south bank of the Khadakvasla Lake. It is about 23 kms away from Poona Rly Station along the PANSHET ROAD. Quite often one equates the location with National Defence Academy which is on the other bank of the lake. PLEASE REMEMBER THAT THE ACCESS ROUTES TO THE INSTITUTE AND NDA ARE ENTIRELY DIFFERENT.

For Assistance, the delegates may dial

Civ 56454 Ext.253/280

How to reach

By TAXI OR AUTORIKSHAW - These vehicles are metered and are available in almost all parts of the town.

By POONA MUNICIPAL TRANSPORT - These are the local passenger buses run by the Poona Corporation. The services are efficient, punctual and prompt. The Institute is connected by Route No 49 from Swargate opposite Hotel Natraj. Swargate bus stop is well connected from every point of the city by the PMT bus routes.

PMT buses do not carry kit and beddings.

Climatic Conditions in June

The Institute is surrounded by hills of the western ghats. Day time is warm, however, morning and evenings are pleasant. It is quite windy during this period. Rains may welcome the delegates.

Beddings Requirements

The delegates are requested to arrange their own beddigns as the rooms are not furnished with these facilities.

A blanket may be necessary for covering in addition to the other usual requirements for the night.

Mosquito nets are preferable. Rain coat is advisable.

THE INSTITUTE puts on beautiful natural garment surrounded by scenic hills and lake view. YOUR STAY WILL BE ENJOYABLE AND OF LEARNING.

GENERAL PROGRAMME

FRIDAY, 21 JUNE 1974

Morning	0900		Registration of delegates
	0930		Inauguration
	1045		Tea
	1115		Invited talk by Dr RP KASTOGI (Subject - Recent developments in the interior ballistics of solid-state propellants) Chairman - Dr SURJIT SINGH
	1215-1300		Visit IAT.
Afternoon	1500		Invited talk by Dr VK THIRUVENKATACHAR (Subject - to be announced later) Chairman - Brig SKM UMAPATHISWARAN
	1545		Tea
	1615-1800		Technical Session - Burning of propellants Chairman - Dr RP KASTOGI

SATURDAY, 22 JUNE 1974

Morning	0830		Invited talk by Dr Y JANARDHAN RAO (Subject - Trajectories for synchronous satellite and space probes) Chairman - Dr MR AGGARWAL
	0915	(a)	Technical Session - Astro-ballistics, Instrumentation and related problems Chairman - Dr Y JANARDHAN RAO
		(b)	Technical Session - Burning of propellants
	1115		Tea
	1130		Invited talk by Brig SKM UMAPATHISWARAN (Subject - Internal and external ballistic design for field gun) Chairman - Dr V RAMAKRISHNA
	1215-1315		Technical Session - Stability and vibration of missiles. Chairman - Prof BS MADHAVA RAO.

.... Contd.

SATURDAY, 22 JUNE 1974

Afternoon	1500	Invited talk by Shri NS VENKATESAN
		(Subject - to be announced later)
		Chairman - Dr WD PATWARDHAN
	1545	Tea
	1615	Technical Session - General Principles of ballistics and mathematical methods.
		Chairman - Dr VR THIRUVENKATCHAR
	1745-1830	Summary
		Chairman - Dr JN NANDA.

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REVISED GENERAL PROGRAMME

TECHNICAL SESSION

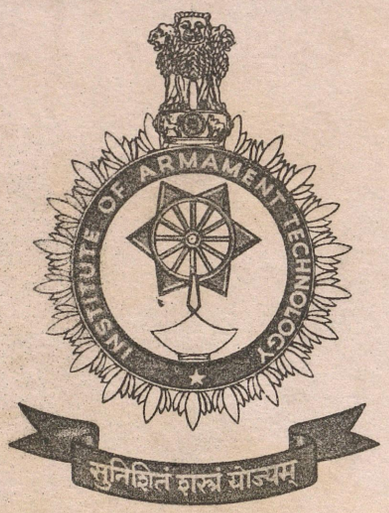
21 Jun 74

1115	Invited talk by Dr Y JANARDHAN RAO Read by Shri S RAO. Chairman - Dr RR AGGARWAL
1215 to 1300	Visit LAT.
1500	Technical Session "Burning of Propellant" Chairman - ~~Dr ML MUNJAL~~ Invited Address by Dr. Rastogi Chairman - Dr Surjit Singh.
1600	Tea
1600 to 1800	Technical Session "Burning of Propellant" Continued

22 Jun 74

0830	Technical Session "Astro-Ballistics etc." Chairman - Dr MC MATHUR
1115	Tea
1145 to 1300	Technical Session "Stability and Vibration of Missiles" Chairman - Dr BS MADHAV RAO
1500	Invited talk by Dr VR THIRUVENKATACHAR Chairman - Dr WD PATWARDHAN
1545	Tea
1615	Technical Session "General Principles of Ballistics etc." Chairman - Dr VR THIRUVENKATACHAR
1745 to 1830	Summary Chairman - Dr JN NANDA

Note: All Sessions from 1500 hrs on 21 Jun 74 are to be held in Lecture Hall No. 1, Block No. 4, Ground Floor.



NON LINEAR BALLISTIC SEMINAR
(21–22 JUNE 1974)

PROGRAMME & ABSTRACT OF PAPERS

JOINTLY ORGANISED

BY

INSTITUTE OF ARMAMENT TECHNOLOGY

&

INSTITUTION OF ARMAMENT TECHNOLOGISTS(INDIA)

CONTENTS

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TECHNICAL PROGRAMME

21 JUNE 1974

Technical Session 1615-1800 Hrs

Section I - Burning of Propellants

dks/

TECHNICAL PROGRAMME

22 JUNE 1974

Technical Session 0915-1115 Hrs

Section III - Astroballistics - Instrumentation and related Problems

Paper No	Title	Author(s)	Affiliation	Abstract Page No
3.1	Trajectory optimization of a multistage rocket	Rao MLN and Shrivastava SK	IISc Bangalore	10
3.2	Weight optimization problem of a multistage rocket vehicle	Tawakley VB	DSL, Delhi	10
3.3	Variational technique in performance analysis of rockets and missiles	Srivastava TN	DSE, Delhi	10
3.4	Calculation and use of orbit predictions	Rauthan DB	ESD, Ahmedabad	11
3.5	Optimum missile shape of minimum ballistics factor for variable skin-frictions.	Jain SC and Tawakley VB	DSL, Delhi	11
3.6	Magnetic hypersonic rarefied flow at the stagnation point of a blunt body with slip and suction or injection.	Nath G	IISc Bangalore	11-12
3.7	A signal processing technique to use LVDT for measurement of recoil velocity of guns	Dani RH	IAT, Poona	12
3.8	Shock waves in earth's atmosphere	Singh VP	TBRL, Chandigarh	12
3.9	Methods for determination of drag coefficient of aerodynamics bodies in free flight ballistic range.	Chadaga PR, Somaiand Mathur MC.	VSSC Trivandrum	13
3.10	Non-linear effects due to leading edge separation on flow past wings and wing-body combinations.	Ramakrishnan SV, and Subramanian NR.	IIT, Madras	13

(11) ?

(12) ?

TECHNICAL PROGRAMME

22 JUNE 1974

Technical Session 1215-1315 Hrs

Section II - Stability and Vibration of Missiles

Paper No	Title	Author(s)	Affiliation	Abstract Page No
2.1 ✓	Nonlinear ballistic equations and the qualitative analysis of the angular motion of a missile.	Sharma KC	IAT, Poona	14
2.2 ✓	Stability of a dirigible body	Rath PC and Sharma SM	IAT, Poona	14
2.3 ✓	On the gyroscopic stability of a lock-fowler projectile.	Namboodiri AV and Chawla YC	IAT, Poona	15
2.4 ✓	On the dynamic stability of a missile	Sharma KC	IAT, Poona	15
2.5 ✓	Librations of a lock-fowler projectile Pt I	Rath PC and Namboodiri AV	IAT, Poona	15-16
2.6	Nonlinear magnus effects on the initial oscillations of a projectile.	Sharma SM	IAT, Poona	16
2.7 ✓	Librations of a lock-fowler projectile Pt II.	Rath PC and Namboodiri AV	IAT, Poona	15-16
2.8. The study of certain non-linear systems etc.		M. N. Rao	DRDL, Hyderabad	

75/7 (II)

TECHNICAL PROGRAMME

22 JUNE 1974

Technical Session 1615-1745 Hrs

Section IV - General Principles of Ballistics and Mathematical Methods

A B S T R A C T

BURNING OF PROPELLANTS

1.1 BURNING RATE STUDIES OF AP-PVC PLASTISOL PROPELLANTS

UC DURGAPAL
MPC RAO
BIT, RANCHI

Burning rates of an ammonium perchlorate - polyvinyl chloride plastisol propellant have been determined in strand burner and in rocket motor firings. Though the Summer-field law for composite propellant burning is satisfied, the theoretical 'granular diffusion flame' model, on which the law is based, does not seem to apply. The burning rate data also fits the pressure index law but two distinct domains are obtained with transition occuring at pressures of 10-15 Kg/cm^2. These domains persist even in presence of catalysts accelarating or decelarating the burning rate, though at high catalyst concentration, the domains tend to merge in some cases. It is concluded that existence of burning rate domains is a characteristic feature of the AP - PVC propellants.

1.2 IMPLICATIONS OF DENSITY FUNCTIONS IN INTERNAL BALLISTICS OF GUNS

SP AGGARWAL
DSE, NEW DELHI

ABSTRACT not received

....2

1.3 SOLUTION OF EQUATIONS OF INTERNAL BALLISTICS FOR THE COMPOSITE CHARGE CONSISTING OF A MIXTURE OF GRAINS OF 'n' SIZES, SHAPES OR COMPOSITIONS

VK GUPTA
ARDE, PASHAN

The four Basic equations of internal Ballistics have been modified for composite charge consisting of 'n' charges. The equations have been solved numerically using Runge-Kutta method. A computer programme is developed which gives all the Ballistic parameters from shot start to shot exit.

1.4 A GENERALIZATION OF VON KÁRMÁN'S METHOD FOR THE EVALUATION OF BURNING RATE EIGEN-VALUES OF LAMINAR FLAMES

V SWAMINATHAN
VR GOWARIKER
VSSC, TRIVANDRUM

Many attempts have been made in the past to obtain laminar flame propagation velocities on the basis of various simplified flame structure models. Of crucial importance in the determination of such velocities is the burning rate eigenvalue. A number of simplified procedures for obtaining fair approximations to this eigenvalue have been suggested in the literature.

In the present communication, a numerical scheme has been proposed for obtaining the burning rate eigenvalues of laminar flames by an n-th order generalization of Von Kármán's method. A closed form solution is difficult even for the case n=2, and for larger values of n, only a numerical technique is to be adopted. It is assumed here, as in the case of Von Kármán's zero and first order approximations, that $1 - \zeta$ can be represented as a polynominal in $1 - \epsilon$ of the form

where is the normalized dimensionless measure

...3

of stagnation enthalpy, ϵ the flux fraction, and C_k's are constants to be chosen to satisfy appropriate differential equations at the hot boundary. The computation of the eigenvalue involves a number of stages; and a set of Computer programs were written in FORTRAN IV on the IBM-360 Computer for carrying out the calculations at each stage. The flow chart of the program and the results obtained for a typical case are presented in the paper. Due to limitations of storage in the Computer, the calculations of the eigenvalues were made only upto n=9. The results obtained by this method compared favourably with the values got by other iterative procedures.

1.5 EROSIVE BURNING OF COMPLEX CONFIGURATIONS OF SOLID PROPELLANT GRAINS

S SUBRAHMANYAM
GK MOORTHY
NAL, BANGALORE

The peculiarities of the erosive burning of complex configurations of solid propellant grains and their influence on the performance of a solid rocket motor are taken up in this paper.

The study is based on the following :-

(i) Heat and mass transfer between the pyrolizing surface and the flow field parallel to the axis of the perforation under conditions of transpiration.

(ii) The dissipation of energy by the vortices generated within the cavities forming the configuration, thus increasing the erosive burning rate.

....4

In regard to (ii) the following considerations hold good :

(a) The size of the vortices depends upon the vortex generator shapes or profiles of the configuration.

(b) The frequency of the vortices is dependent on the flow velocity of combustion gases within the perforation.

(c) The effect of stretching of the vortex tubes and their dimensions based on the Kolmogorov microscale.

(d) The transfer of dissipated energy to the surface under conditions of the calculated effective turbulent viscosity.

As an example, a wagon wheel configuration is chosen and detailed calculations are made for the erosive burning in terms of its (i) progressive perimeter (ii) neutral perimeter (iii) regressive perimeter.

A theoretical approach based on the foregoing would be able to predict the performance required for a particular mission.

A computer programme is devised for carrying out detailed calculations.

The experimental part of the investigations would be taken up as soon the erosive burning rate measurement equipment is set up.

.... 5

1.6 SOLUTION OF INTERNAL BALLISTIC EQUATIONS FOR RECOILLESS GUNS

VK GUPTA
ARDE, PASHAN

Internal Ballistic Equations for the three cases of recoilless guns eg in which shot start is before, at or after the nozzle start have been numerically solved, using Runge-Kutta method. A computer programme is developed that can be used to give Ballistic parameters, effect of loading conditions and pressure/time, pressure/velocity/space curves for such type of guns. Pressure/velocity/space curves calculated for two guns with this method have also been shown.

1.7 ROLE OF IGNITION CATALYSTS IN THE COMBUSTION OF HYBRID ROCKET PROPELLANTS

NL MUNJAL
MG PARVATIYAR
BIT, RANCHI

Ammonium vandadate has been found out to be the most effective catalyst in reducing the ignition delay of amine formaldehyde type hybrid fuels with RFNA. In order to explain the role of this catalysts, some of the electrical properties viz., determination of charge carrier, concentration, mobility, mean free time etc. have been carried out. Thermo-chemical measurements of these hybrid propellants in presence of this catalysts have also been carried out.

.... 6

1.8 INFLUENCE OF ORGANO TIN COMPOUNDS OF BURNING RATE OF DOUBLE BASE ROCKET PROPELLANTS

MG LANDGE
HARIDWAR SINGH
KRK RAO
SK SINHA
ERDL, PASHAN

In the course of investigations on platonisation of double base rocket propellants, it appeared of interest to study the effect of some organometallic tin compounds. Results of the effect of two such compounds are reported in this publication, which show catalytic and platonising influence.

1.9 THEORETICAL THRUST/TIME CURVES FOR SOLID PROPELLANT ROCKET MOTORS HAVING NON CONSTANT BURNING SURFACES

VK GUPTA
ARDE, PASHAN

The internal Ballistic Equations for recoilless guns have been modified for the condition when the nozzle is open but shot has not started. The equations which cater for the fall in temperature due to the expansion and leakage of gases through the ventury have been numerically solved to give the thrust/time curve for the solid propellant rocket motor.

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1.10 ON A NEW CRITERION FOR ASSIGNING THE WEB SIZE OF PROPELLANT GRAINS

SURESH CHANDRA
ARDE, PASHAN

The conventional criterion of determining the web-size of a propellant grain cannot be applied in case of multitubular shape. This led to rejection of the prevailing methods, used for other shapes, for multitudes and ever since late fifties quite a good amount of research has been directed towards development of special methods to deal with propellants of such a shape. In this paper determination of web-size has been approached from a different aspect altogether and has been defined as the diameter of the largest sphere that can be drawn in the homogenous propellant grain. With this criterion of assigning the web size it will be possible to chose f as independent variable upto all burnt in case of multitubular propellant also; and would therefore, admit direct integration of internal ballistic equations without any compromise on its form function.

1.11 STUDIES ON COMBUSTION OF COMPOSITE SOLID ROCKET PROPELLANTS

RP RASTOGI
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A comparative study of combustion of polystyrene (PS) and copolymer (copolymer of styrene and oxygen)/ammonium perchlorate (AP) composites has been made in order to investigate the role of peroxide linkage present in the copolymer and to study interface reactions in the condensed phase. For this purpose, burning rate, thermal degradation kinetics, heat of combustion, flame temperature and surface temperature have been measured. Decomposition of solid propellants relevant in

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combustion processes has also been studied by differential scanning calorimetry (DSC).

The burning rate and thermal degradation rate are found to be higher in case of copolymer/AP propellants.
The thermal degradation data obey the equation:

$$(2/t) \log W = kW + \text{constant}$$

where k is a constant which depend on temperature and W is the fraction volatalised at time t. Although k is lower for copolymer propellant but dW/dt is higher for the same. The enhanced degradation rate is due to weaker -O-O- (peroxide) bond present in the copolymer. Both surface and flame temperature for copolymer propellants are higher than PS propellants.

Enthalpy changes for decomposition of polymers (PS and copolymer), AP and the corresponding propellants have been estimated from DSC thermograms. The results show that solid-solid, solid-liquid and solid-gas reactions occur during decomposition with a resultant enthalpy change amounting to - 461 $\pm$ 62 cal/gm and - 502 $\pm$ 27 cal/gm for PS and copolymer propellants. Energy of activation of the net decomposition process is estimated to be 41 $\pm$ 5 and 35 $\pm$ 6 K cal/mole for PS and copolymer propellants respectively. Isothermal decomposition of the propellants have also been made.

1.12 CHEMICAL AND BALLISTICS STABILITY OF DEGN BASE PROPELLANTS

E PADMINI
SS PHANSALKAR
HK SINGH
ERDL, PASHAN

Double base propellants containing Diethylene Glycol Dinitrate and methyl centralite in lieu of NG and Ethylcentralite respectively have been introduced in Service for the first time in India. Their chemical and ballistics stability have been studied. The results indicate that they do not possess inferior stability to Service double base propellants.

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1.13 RECENT ADVANCES IN THE DETERMINATION OF CHEMICAL STABILITY OF PROPELLANT

PK MISRA
HK SINGH
ERDL, PASHAN

The transformation products of common stabilizers such as centralite and DPA in the initial stages also act as stabilizer. Their presence in sentencing the propellant should also be taken into consideration together with the viscosity of NC in propellant. A scheme for the inspection is proposed and merits and demerits of some of the stability tests are discussed.

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ASTRO-BALLISTICS - INSTRUMENTATION AND RELATED PROBLEMS

3.1 TRAJECTORY OPTIMIZATION OF A MULTI-STAGE ROCKET (SATELLITE LAUNCH VEHICLE)

MLN RAO
SK SINHA
SK SHRIVASTAVA
IISc, BANGALORE

An optimal thrust vector control programme to maximise the pay load of a multi-stage rocket used for launching a near-earth satellite is presented. The two-dimensional model includes the effects of the earth's rotation and atmospheric drag and lift. The problem with end-constraints, free terminal time and finite parametric discontinuities is simulated on an IBM 360/44 computer using a modified version of Bryson and Denham's steepest ascent technique. An illustrative analysis of the rockets of the class of SLV-3 suggests a possibility of improving the performance substantially.

3.2 WEIGHT OPTIMIZATION PROBLEM OF A MULTI-STAGE ROCKET VEHICLE

VB TAWAKLEY
DSL, DELHI

ABSTRACT not received

3.3 VARIATIONAL TECHNIQUE IN PERFORMANCE ANALYSIS OF ROCKETS AND MISSILES

TN SRIVASTAVA
DSE, DELHI

ABSTRACT not received

3.4 CALCULATION AND USE OF ORBIT PREDICTIONS

DB RAUTHAN
ESD, AHMEDABAD

The use of artificial satellites in fields like communications, weather-predictions, study of earth's resources etc. is well recognised. This has necessitated the predictions of correct satellite orbits and the pointing data calculations of satellites so that the earth based telemetry equipments be correctly pointed to receive signals or transmit commands to them. The orbit of a satellite is defined by six parameters known as the "Orbital Elements" which change gradually because of various perturbing effects.

In the present paper a method is developed to improve the preliminary orbital elements of a satellite from the observations at later times. The predicted values of observation-variables at certain instant of time are compared with the corresponding observed values. The differentials of the orbital elements are assumed small so that their squares and higher powers are negelected. The resulting equations are solved by the method of least squares.

3.5 OPTIMUM MISSILE SHAPE OF MINIMUM BALLISTICS FACTOR FOR VARIABLE SKIN FRICTIONS

VB TAWAKLEY
SC JAIN
DSL, DELHI

ABSTRACT not received

3.6 MAGNETIC HYPERSONIC RAREFIED FLOW AT THE STAGNATION POINT OF A BLUNT BODY WITH SLIP AND SUCTION OR INJECTION

G NATH
IISc, BANGALORE

The hypersonic viscous flow of a slightly rarefied electrically

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conducting gas in the stagnation region of a blunt body with an applied magnetic field, slip and suction or injection has been studied. The similarity solutions of the boundary layer equations have been obtained numerically using quasilinearization technique. The results indicate the extent to which the magnetic field, the slip parameter and the mass transfer parameter affect the heat transfer rate.

3.7 A SIGNAL PROCESSING TECHNIQUE TO USE LVDT FOR MEASUREMENT OF RECOIL VELOCITY OF GUNS

RH DANI
IAT, POONA

Presently the measurement of recoil velocity by use of LVDT technique is done by a composite rod of alternate sections of steel and brass of equal length forming the moving core of the differential transformer. This method can give average velocity at discrete points only. This paper describes a signal processing technique which can give continuous plot of velocity and displacement.

3.8 SHOCK WAVES IN EARTH'S ATMOSPHERE

VP SINGH
TBRL, CHANDIGARH

Propagation of shock waves, produced by rockets, or objects moving with supersonic speed in earth's atmosphere are studied by using Whitham's method of characteristics. For the general case of ascending spherical shock waves, it is found that shock wave first decays but after reaching a specific height, its strength starts increasing. For the case of plane oblique shocks its strength increases as it moves upward. In the case of plane shocks, analytical expression for the shock velocity is found.

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TECHNICAL PROGRAMME

22 JUNE 1974

Technical Session 1215-1315 Hrs : Chairman Dr BS Mathur ras.

Section II - Stability and Vibration of Missiles

Paper No	Title	Author(s)	Affiliation	Abstract Page No
2.1	Nonlinear ballistic equations and the qualitative analysis of the angular motion of a missile.	Sharma KC	IAT, Poona	14
2.2	Stability of a dirigible body	Rath PC and Sharma SM	IAT, Poona	14
2.3	On the gyroscopic stability of a lock-fowler projectile.	Namboodiri AV and Chawla YC	IAT, Poona	15
2.4	On the dynamic stability of a missile	Sharma KC	IAT, Poona	15
2.5	Librations of a lock-fowler projectile Pt I	Rath PC and Namboodiri AV	IAT, Poona	15-16
2.6	Nonlinear magnus effects on the initial oscillations of a projectile.	Sharma SM	IAT, Poona	16
2.7	Librations of a lock-fowler projectile Pt II.	Rath PC and Namboodiri AV	IAT, Poona	15-16
2.8	The Study of certain nonlinear systems etc	H N Rao	DRDL	

3.9 METHODS FOR DETERMINATION OF DRAG COEFFICIENT OF AERODYNAMICS BODIES IN FREE-FLIGHT BALLISTIC RANGE

PR CHADAGA
P SOMA
MC MATHUR
VSSC, TRIVANDHUM

A Review of testing procedures and data analysis for determination of drag coefficient of Aerodynamic models in a free-flight ballistic range is discussed in detail. Various techniques employed in data reduction are elaborated. Sample calculations for model design and test requirements for free-flight testing has been worked out. The effect of drag coefficient on Range and model parameters are also presented.

3.10 NON-LINEAR EFFECTS DUE TO LEADING EDGE SEPARATION ON FLOW PAST WINGS AND WING-BODY COMBINATIONS

SV RAMAKRISHNAN
NR SUBRAMANIAN
IIT, MADRAS

To calculate the range of a ballistic missile it is essential to find out the pressure distribution on it. The pressure distribution on a ballistic missile is highly affected by the flow separation which is a non-linear phenomenon. The first step in evaluating the effects of flow separation would be to find its effect on a flat plate.

Here the method given by Mangler and Smith for the analysis of flow past slender delta wings with leading edge separation, is discussed in detail. The numerical method has been improved by replacing the nested iteration procedure used by Mangler and Smith by a Newton-Raphson method. This has improved the convergence of the non-linear equations. The extension of method for wing-body combinations is also given.

The shape of the vortex sheet and the core position have been obtained and compared with Mangler's results.

STABILITY AND VIBRATION OF MISSILES

2.1 NON LINEAR BALLISTICS EQUATIONS AND THE QUALITATIVE ANALYSIS OF THE ANGULAR MOTION OF A MISSILE

KC SHARMA
IAT, POONA

In part I of this paper, apart from deriving the air-force system from Maple and Synge formulations and the equations of angular motion of a clean-symmetric body, motion and stability due to a non-linear aerodynamic moments have been discussed.

In the second part, the sufficient stability conditions have been obtained from the second method of Lypunov. Conditions have been grouped for stability at small and large angles of attack. The three cases examined are (i) Non linear aerodynamic moment associated with complete non-varying dissipations (ii) Non-varying linear aerodynamic moment and completely non-linear dissipations (iii) Completely non-linear form.

2.2 ON THE STABILITY OF A DIRIGIBLE BODY

PC RATH
SM SHARMA
IAT, POONA

A time dependent stability problem of the coasting motion of a dirigible body is studied with the help of oscillation theory of differential equations. It is observed that the usual static stability condition $J_M < 0$, ensures the oscillatory motion of the body and the requirements for damping of the oscillations provide for an upper majorant for J_M.

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2.3 ON THE GYROSCOPIC STABILITY OF A LOCK-FOWLER PROJECTILE

AV NAMBOODIRI
YC CHAWLA
IAT, POONA

The Cranz-Mayveski stability condition gives for a lower bound to the axial spin of a projectile to ensure gyroscopic stability. Cetaev modified this condition to link this stability reserve with the initial disturbance and the deviation of the axis of the projectile from its normal position. This note extends Cetaev's condition to the case when the initial yawing motion of the projectile is non-linear.

2.4 ON THE DYNAMIC STABILITY OF A MISSILE

KC SHARMA
IAT, POONA

The P-method given by Parks and Pritchard has been used to discuss the stability behaviour of a missile in free flight. General stability criteria for aerodynamic stabilisation have been obtained for slowly varying coefficients. The effect of pressure gradient on the stability of a coasting rocket has been explicitely examined. It is observed that the positive magnus moment parameter ensures stability whereas a negative moment parameter would enhance the requirements of a larger stability margin.

2.5 2.7 LIBRATIONS OF A LOCK-FOWLER PROJECTILE

PC RATH
AV NAMBOODIRI
IAT, POONA

The librational and various asymptotic motions of a Lock-Fowler projectile has been studied in detail. The non-linear librational motion

problem has been solved completely in closed form with the help of Weierstrassian elliptic functions. All possible unsteady motions of the projectile has been classified using a technique of Routh. It has been observed that the libration of the projectile is confined to two levels of no velocities which is not usually observed in case of an ordinary gyroscope. It is also proved that cusps could occure at the levels of maximum yaw of the projectile for which conditions have been obtained.

2.6 NON-LINEAR MAGNUS EFFECTS ON THE INTIAL OSCILLATIONS OF A PROJECTILE

SM SHARMA
IAT, POONA

The initial nutational oscillations of a spinning projectile which is gyroscopically stable, has been examined subject to a non-linear Magnus torque. Such a Magnus torque has been suggested by Kent. An approximate solution of the non-linear equation in yaw has been obtained by the method of equivalent linearisation and this is found to agree qualitatively well with the computer solution of the non-linear equation. It is observed that for a certain value of the parameter λ^2, which characterises the non-linear Magnus torque, the amplitudes of oscillations neither grow nor decay. Further, self-excited and stationary oscillations are also found to exist.

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GENERAL PRINCIPLES OF BALLISTICS AND MATHEMATICAL METHODS

4.1 SOME MATHEMATICAL ASPECTS OF HIGH ALTITUDE GUNNERY PART I : "PROBLEM OF PREDICTED FIRE"

GS GUPTA
ARDE, PASHAN

The performance of weapon systems in High Altitude Conditions is very significantly different than that obtainable in plains. But neither all the parameters determining the value of this performance difference nor the contribution by each of the known parameters to it are exactly known. In this paper some theoretical aspects of the variation in Ballistic performance of artillery projectiles viz predicability of Range with respect to meteorological conditions prevalent in High Altitudes are discussed. Attempts are made to show that the existing methods of applying meteorological corrections are neither correct nor adequate for the accurate firings in high altitudes By analysis it is found that the existing methods are only reasonably accurate for plains. Magnitude of errors, creeping in, due to large deviations of prevalent meteorological conditions from the standard conditions and the adoption of existing gunnery methods have been deduced.

4.2 UNIFIED THEORY OF INTERNAL BALLISTICS OF GUNS BASED ON AN IMPROVED VERSION OF GAS DENSITY FUNCTION

NK CHOPRA
DSE, DELHI

ABSTRACT not received

4.3 ASSESSMENT OF LETHALITY FOR HIGH EXPLOSIVE WARHEADS

OP MALHOTRA
IAT, POONA

The end effect of all sophistication in a weapon system is to maximise the damage caused to the target. In order to assess this damage there is a requirement to develop a statistically reliable method. In the past assessment methods used were often unreliable and unsound judged from the modern standards. However, with the development of the computer and new statistical tools lot of work has been done in this field after the second world war both in UK as well as USA and various methods have been developed. In this article a review of these methods along with the lines on which further work should proceed in our country has been discussed.

4.4 SOME MATHEMATICAL ASPECTS OF HIGH ALTITUDE GUNNERY PART II: PROBLEM OF INTERACTIVE ERRORS AND THEIR ACCOUNTABILITY

GS GUPTA
ARDE, PASHAN

Some studies connected with the effects of pressure and air temperature changes on the magnitude of interactive effect errors and its variation with respect to these two parameters have been made. Various direct methods of accountability of interactive effect errors have been considered and the relative merits and demerits of each of these have also been discussed briefly. It has further been shown that the interactive effect errors deduced as percentage change in the value of standard ballistic coefficient can be converted in terms of fictitious changes in either the prevailing value of atmospheric pressure or air temperature. Based on these two approaches various measures are suggested either of which, depending on convenience can be adopted to counteract the interactive effect errors.

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4.5 BALLISTICS OF EJECTION SEATS

MR PATKAR
ARDE, PASHAN

With ever increasing speeds of military aircraft, safe emergency escape of aircrew is possible only by explosive assisted ejection seats. The Design of ejection system in conjunction with the aircraft as a whole, is governed primarily by study and application of accurate ballistics of ejection seats.

2. The following aspects have been discussed in the paper :-

(a) Evolution of ejection seats

(b) External ballistics

- (i) Theory of ejection
- (ii) Calculation of trajectory of ejection seat.

(c) Internal ballistics

- (i) Cartridge design
- (ii) Propellant design
- (iii) Gun design

(d) Experimental technique of evaluation of ballistic parameters.

- (i) Vented vessel
- (ii) Seat Ejection tower
- (iii) Instrumentation

(e) Analysis of experimental data

- (i) Interdependency of ballistic parameters
- (ii) Co-relation between theoretical values and measured values

(f) Scope for further studies in the field.

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4.6 ON THE EVALUATION OF WEIGHTING FACTORS FOR ICAO TYPE GENERAL ATMOSPHERE

SURESH CHANDRA
ARDE, PASHAN

In applied ballistics weighting factors are used to account for the variations in range (or any other trajectory element) due to non-uniform meteorological variations in different layers of the atmosphere. In this paper the equations of variation have been derived assuming the standard atmosphere to be made up of portions having either constant temperature or constant temperature gradient (such as in ICAO atmosphere) using the method of adjoints. Algorithm for the solution of these equations and thereafter the evaluation of weighting factors has been developed for fast digital computation.

4.7 MODIFICATIONS IN HYDRODYNAMICAL PROBLEM OF HIGH-LOW PRESSURE GUN AND THEIR APPLICATIONS TO ISOTHERMAL AND NON-ISOTHERMAL MODELS

PS VARMA
DSE, DELHI

This paper deals with the theory of high-low pressure gun based on isothermal and non-isothermal models with the application of modified pressure distribution and kinetic energy derived on the basis of the actual gas density

$$\rho = \frac{C(z - N)}{Ko + Ax - bC(z - N)}$$

of the propellant gases in the second chamber and the bore of the gun. A finite velocity vo (equal to the local velocity of sound) with which the propellant gases enter in the second chamber has been taken into

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consideration for working the ballistics solution for this gun. The modified pressure distribution equation, derived on the basis of δ, has been used in the equation of motion of the projectile so as to depict the effect of the actual gas density function in the theory of high-low pressure gun for the said models. The technique for working out the series solution has also been added.

4.8 ADOPTION OF A NEW STANDARD ATMOSPHERE FOR HIGH ALTITUDE BALLISTICS

GS GUPTA
ARDE, PASHAN

Standard Ballistic atmosphere is in vogue in our country for studying the ballistics of the projectiles. Its inadequacy as reference atmosphere for the high altitude ballistic work has been shown. Effects of abnormal meteorological conditions on various parameters of external ballistics have been discussed briefly. Alternative set of atmospheric conditions to be taken as standard on the tentative basis for high altitudes are specified. It is further recommended that a definite set of new atmospheric conditions be evolved to constitute the standard atmosphere for high altitudes.

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LATE ABSTRACTS

1.2 IMPLICATIONS OF GAS DENSITY FUNCTION IN INTERNAL BALLISTICS OF GUNS

SP AGGARWAL
DSE, DELHI

In this paper the effects of New Modified Version of gas density function in internal ballistics of guns have been discussed.

The adoption of this gas density function which takes account of an important aspect of gradual burning of the propellant grains has removed certain physical anomalies arising out due to earlier gas density functions. A comparative study of the various ballistics parameters i.e. maximum pressure, all-burnt position and muzzle velocity etc. has been dealt by taking an example of 3.7" A.A. Gun. The modified pressure-space curves and velocity-space curves due to various gas density functions have been studied on gun design considerations.

3.3 VARIATIONAL TECHNIQUE IN PERFORMANCE ANALYSIS OF ROCKETS AND MISSILES

TN SRIVASTAVA
DSE, DELHI

Variational approach to optimization problems of rockets and missiles is discussed. The problem of rocket motion in vertical flight is analysed under more than one bounded control variables and conditions for extremal path are investigated with possible discontinuities. In the end particular cases are analysed with special reference to mass flow rate limited systems.

4.2 UNIFIED THEORY OF INTERNAL BALLISTICS OF GUN BASED ON BETTER APPROXIMATION OF GAS DENSITY FUNCTION

NK CHOPRA
DSE, DELHI

In this paper a unified theory of internal ballistics of guns has been developed by taking the system of equations of Recoil-less high-low pressure gun based on the actual gas density function. The theory covers the systems of equations for the Recoil-less gun, for the high-low pressure gun, for the orthodox gun and for solid fuel rockets as particular cases based on the new and better deduced gas density functions. In the end the solutions of the ballistics equations for the RCL H/L Gun are given, before all-burnt for the isothermal model and after all-burnt for the non-isothermal model.

3.11 AMPLITUDE AND PHASE ERRORS IN MONOPULSE CONVERTERS

BVT RAO
IAT, POONA

In monopulse tracking radars, converters are employed to make it feasible for the system to operate on two receivers or even one receiver instead of the conventional three. This, while reducing the equipment required, leads to greater system reliability and balancing.

This paper discusses three distrinct cases of the effect of amplitude and phase unbalance, on a monopulse converter isolation. In each case, the isolation of the inphase and quadrature components respectively, have been calculated on some simplifying assumptions.