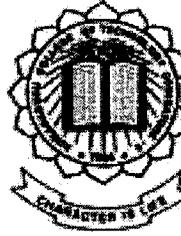# PREVENTION OF ENGINE DERATION IN TEST CELL-I

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

In

MECHANICAL ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY, COIMBATORE

ANNA UNIVERSITY:: CHENNAI 600025

MAY 2009

ANNA UNIVERSITY: CHENNAI 600025

BONAFIDE CERTIFICATE

It is certified that this project report entitled **"PREVENTION OF ENGINE DERATION IN TEST CELL - I"** is the bonafide work of

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This is to certify that **M. SUDHIR ESWARAN**, Reg. No – 71205114050, Final Year – B.E [Mechanical Engineering] student of **Kumaraguru College of Technology, Coimbatore** has successfully completed his Project titled **"Prevention of Engine Deration in Test Cell"** at our Organization from **December 01, 2008** to **December 31, 2008.**

During this period his performance and conduct were found to be good.

We wish him success in all his future endeavors.

F ISRAEL INBARAJ
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has successfully completed his Project titled **"Prevention of Engine Deration in Test
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Human Resources Manager

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ABSTRACT

Keywords : Deration , inlet air restriction, induction air requirements , incomplete combustion , test cell design , air change method

The increase of the range of power products provided by Caterpillar Power India Private Ltd has created the necessity for increased testing capacity. This has been achieved by adapting the test cells to accept a wider range of engines and the setting up of a fifth test cell. In the process, Test Cell I has been modified for the C-18 DITA, 3412-DITA-725 KVA and 3412-773D HEUI engines. The space restrictions and insufficient ventilation has resulted in increase of cell ambient temperature beyond test specifications causing deration of the above-mentioned engines. The objectives of this project include the collection of relevant test data and calculation of ventilation and intake air requirements. The data indicated an discrepancy in the performance of C-18 due to the differential heating of the air filters .The proposed forced ventilation and ducting facilities for the given test cell were designed based on the observed data and technical specifications.

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COMPANY PROFILE

Caterpillar Inc. (NYSE: CAT) is a United States-based corporation headquartered in Peoria, Illinois. Caterpillar (commonly referred to simply as CAT) is, according to their corporate website, "the world's largest manufacturer of construction and mining equipment, diesel and natural gas engines, and industrial gas turbines."

Famous for their products featuring caterpillar tracks and a distinctive yellow paint scheme, Caterpillar produces a wide range of engineering vehicles, including the range of Caterpillar bulldozers. Former presidents George W. Bush and Bill Clinton have visited the Peoria area to see the company, and President Barack Obama visited in February 2009 on a stopover on his way to Lincoln celebrations in Springfield.

Caterpillar is one of the thirty companies whose stock is tracked in the Dow Jones Industrial Average. It is a Fortune 500 company, ranked number 50 in 2008, and first in its industry, with more than $30 billion in assets.

History

The story of Caterpillar Inc. originates in the late 19th century, when Daniel Best and Benjamin Holt experimented with ways to fulfill the promise that steam tractors held for farming. By 1904, these large steam-powered tractors had been plowing California fields for 14 years, and occasionally got bogged down in the soft soil, especially after heavy rains. Once stuck in the mire, they were difficult to pull free, even with teams of horses. Their great weight typically rested on four metal wheels.

One solution employed to alleviate this problem was to lay a temporary plank road ahead of the steam tractor, but this was time-consuming, expensive, and interfered with earthmoving. Holt came up with the idea to carry the road with the vehicle. On

November 24, 1904 he added wooden block-linked treads around the idlers on Holt No.77, his test tractor. The results were impressive, and the modern tractor was born. Caterpillar became famous for its Caterpillar 30 and its Caterpillar 60 tractors.

In 1909, Benjamin Holt bought the abandoned but relatively new manufacturing plant of a tractor company that had failed in East Peoria, Illinois. The location offered Holt everything he needed in a manufacturing center, and despite the hefty amount of capital needed for retooling the plant, the venture proved so profitable that by 1911 the factory employed 625 people. Around that time, Holt Manufacturing began exporting its tractors to Argentina, Mexico, and Canada, in addition to their domestic sales. The Holt Manufacturing Company later pioneered the use of the continuous track during World War I. Their crawler tractors inspired the first military tanks, which helped end World War I.

Caterpillar formed on April 15, 1925 with the merger of *Holt Manufacturing Company* of Stockton, California and the *C. L. Best Gas Traction Company* of San Leandro, California, forming the *Caterpillar Tractor Co.* Sales the first year were US$13 million. By 1929, sales climbed to $52.8 million, and CAT continued to grow throughout the Great Depression of the 1930s.

After the companies merged, Caterpillar went through many changes, including the adoption of the diesel engine. During World War II, Caterpillar products found fame with the Seabees, Construction Battalions of the United States Navy, who built airfields and other facilities in the Pacific Theater of Operations. During the post-war construction boom, the company grew at a rapid pace and launched its first venture outside the U.S. in 1950, marking the beginning of Caterpillar's development into a multinational corporation.

The Conglomerate

In addition to increasing sales of its core products, much of Caterpillars growth has been through acquisitions, including:

Company	Location	Date	Products	Notes
Towmotor	Mentor, OH	1965	Forklifts	Later became Caterpillar Mitsubishi Forklifts, 80% owned by Mitsubishi
Solar Turbines	San Diego, CA	1981	Natural gas turbines	Founded in 1927 as Prudden-San Diego Airplane Company; assets acquired from International Harvester
Barber Green	Minneapolis, MN	1991	paving products	Renamed Caterpillar Paving Products
Krupp MaK Engines	Kiel, Germany	1997	Marine diesel engines	Renamed Caterpillar Motoren (but still uses MaK brand name)
Perkins Engines	Peterborough, UK	1998	Small diesel engines	Produces both Cat

				and Perkins branded engines
F.G. Wilson	Larne, Northern Ireland	1999	Generators	Produces both Cat and Olympian branded gen-sets
Hindustan Motors Earthmoving Equipment Division	Chennai, India	2000	Construction equipment	Renamed Caterpillar India
Elphinstone	Burnie, Australia	2000	Underground mining equipment	Renamed Caterpillar Underground Mining
Sabre Engines Ltd.	United Kingdom	2000	Marine engines	
Wealdstone Engineering Ltd.	Rushden, United Kingdom	2004	Remanufacturer of gasoline and diesel engines	
Williams Technologies, Inc.	Summerville, South Carolina	2004	Remanufacturer of automatic transmissions, torque converters and engines	
Turbomach SA	Riazzino, Switzerland	2004	Packager of industrial gas turbines and related	

			systems	
Progress Rail	Albertville, Alabama	2006	Railroad equipment remanufacturing	
Hindustan PowerPlus Ltd.	Mathagondapalli, India	2006	Engine components and heavy-duty diesel engines	Buyout of joint venture formed in 1988. Renamed Caterpillar Power India Private Ltd. Merged into Caterpillar India in 2008.
Eurenov	Chaumont , France	2007	Automotive component remanufacturing	
Blount International, Inc. - Forestry Division	Portland, Oregon	2007	Timber harvesting and processing equipment, loaders and attachments	
Shandong Engineering Machinery (SEM)	China	2008	Construction equipment	
LOVAT	Canada	2008	Tunnel boring machines	
Shin Caterpillar	Sagami & Akashi,	2008	Construction	Joint venture since

Mitsubishi	Japan		equipment	1963, with purchase of majority became Caterpillar Japan Ltd.
MGE Equipamentos & Serviços Ferroviários	Brazil	2008	Railroad equipment remanufacturing	
Gremada Industries	West Fargo, North Dakota	2008	Remanufacturing transmissions, torque converters, and final drives	

Business Lines

As of the first quarter of 2006, 44% of Caterpillar's sales are to overseas customers. Caterpillar products are sold in nearly 200 countries. The company has a worldwide network of 220 dealers: 63 dealers in the United States and 157 in other countries. Caterpillar products and components are manufactured in 51 plants in the United States and 58 plants in Australia, Belgium, Brazil, Canada, England, France, Germany, Hungary, India, Indonesia, Italy, Japan, Mexico, the Netherlands, Northern Ireland, the People's Republic of China, Poland, Russia, South Africa and Sweden. Caterpillar also licenses or subcontracts the manufacture of Caterpillar-branded clothing, hats, footwear, and other consumer products.

Caterpillar's historical manufacturing home is in Peoria, Illinois, where its world headquarters and core research and development activities are located. Although

Caterpillar has "farmed out" much of its local parts production and warehousing to outside firms, it still has four major plants in the Peoria area: the Mapleton Foundry, where diesel engine blocks and other large parts are cast; the East Peoria factory, which has assembled Caterpillar tractors for over 70 years; the Mossville engine plant, built after World War II; and the Morton parts facility.

Engines

A portion of CAT's business is in the manufacturing of diesel and natural gas engines and gas turbines, which, in addition to their use in the company's own vehicles, are used as the prime movers in locomotives, semi trucks, and ships, as well as providing the power source for peak-load power plants and emergency generators.

Caterpillar India Pvt. Ltd-Power Services Division(Hindustan PowerPlus Ltd)

It was formed by a Buyout of joint venture formed in 1988. Renamed Caterpillar Power India Private Ltd. It was merged into Caterpillar India in 2008. Their product lines include

Engines & Transmissions

- o Diesel Engines
    - Genset Engines (3400, 3500, 3600, C-18 Series)
    - Captive Engines (3400, 3500, C-18 Series)
- o Natural Gas engines
    - 3300 Series
    - 3400 Series
- o Transmissions
    - 424 B Back Hoe Loader Transmission

CHAPTER 1.PROJECT DEFINITION

1.1 Problem Definition:

The ideal stated conditions for testing the above mentioned engines specifies an ambient temperature of 25 ~30 Deg C at 101.325 Kpa. The heat emitted by the engine into the test cell causes a decrease in localized pressure around the engine including the air intakes. This causes a fall in the localized air density resulting in insufficient mass of air for combustion. This phenomenon appends to the deration of engines due to the 1000 m elevation of Hosur above MSL. This has become prominent during the test cycles of the mentioned engines. Hence, sustained loading of these engines at maximum capacity displays a decreasing trend of observed power from rated power. The deration was maximum for the C-18 engine with 600 KVA rating.

1.2 Impact:

The deration of the engines in this particular test cell has caused concerns that the incapability of the cell shall overshadow inherent problems in the engines under test. Moreover, the increased cell temperature causes discomfort to workers venturing into the cell during washing and leak-inspection. This condition also forces the elongation of the test cycle to allow the ambient air to cool down to acceptable levels.

1.2 Scope:

The scope of the project includes observation of test cycles, analysis of existing space and other facilities to synthesize a feasible and viable solution.

1.3 Time Frame:

The student team was allotted a period of one month from 01/12/2008 to 31/12/2008 for the completion of necessary ground work in the plant and submission of their proposal.

CHAPTER 2.ENGINE SPECIFICATIONS

2.1 Engine Specifications – C18-600KVA

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine

	Technical particulars of C-18 (Generator set package)		
	Description / KVA Rating 0.8 p.f. 50 Hz	KVA	600
	Engine Model		C18
	TMI reference number		TM2245
	Version		Low Emiss
1	Power rating of the engine @ 1500 rpm	EkW	480
2	Gross Engine BHP	BHP	706
3	Gross Engine KW	BKW	527
4	Typical Alternator Efficiency @ 100% load	%	93.9%
5	Power Drawn from engine w/o radiator fan	BKW	511
6	Radiator fan power	kW	14
7	Engine Dimensions (Approximate)		
	Length(Engine Alone W/O Cooling System)	mm	1860
	Width(Engine Alone)	mm	1060
	Height(Engine Alone)	mm	1885
8	Generator Set Package Dimensions (Approximate)		
	Length	mm	3950
	Width	mm	1900
	Height	mm	2150
10	No. of Cylinders	No.	6
11	Bore & Stroke	mm	145 x 183
12	Displacement	L	18.13
13	Compression ratio	No.	14.5 : 1
14	BMEP of the engine	kPa	2325
15	Direction of rotation (SAE Std.) – FW End		CCW
16	Engine Arrangement	Deg.	Inline
17	Firing order		1-5-3-6-2-4
18	Aspiration of engine		TAC (ATAAC)
19	Piston speed of engine	m/sec	9
20	Max. overspeed allowed (Trip set at)	rpm	1770
21	Total dry weight of engine (w/o cooling system)	kg	1650 (approx)
22	Total Weight of the Generator set package	kg	3750

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

	Technical particulars of C-18 (Generator set package)		
	Description / KVA Rating 0.8 p.f. 50 Hz		600 KVA
	Engine Model		C-18
	Unit reference number		DK99262
	Version		Low Emiss
23	Dry Weight of Radiator	kg	200
24	Dry Weight of Heat Exchanger	kg	234
25	Max. allowable static bending moment	Nm	1469
	at the rear face of flywheel housing		
26	Friction horse power lost	kW	20
27	Mechanical efficiency of the engine	%	96.34%
28	Thermal efficiency of the engine	%	39.68%
29	Reference Standards for Engines *		ISO 3046
	Exhaust system		
1	Exhaust system back pressure (max.)	kPa	10
2	Diameter of engine exhaust outlet (inside)	mm	203.2
3	Muffler/Silencer Restriction(Residential) P_s	"H$_2$O	6
4	Exhaust flange details		
	- No. of holes	No.	8
	- Dia. of holes	mm	10.5
	- PCD	mm	250.95
	- No. of exhaust outlets		1
5	No. of exhaust outlets on engine	No.	1
6	Max. allowable weight of exhaust system on engine	kg	27
7	No. of residential silencers supplied	No.	1
8	Noise reduction silencer(s)-Typical	dB(A)	25
9	Weight of muffler(Horizontal/Vertical mtg.allowed)	kg	98
10	Exhaust gas flow rate ** (+/- 6%)	CFM	4167
11	Exhaust gas flow rate ** (+/- 6%)	M3/Min	118
12	Exhaust gas temp.(stack) ** (+/- 8%)	Deg. C	537
	Center of Gravity position - Bare Engine(approx.)		

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

	Technical particulars of C-18 (Generator set package)		
	Description KVA rating @ 150°C	KVA	600
	Engine Model		C18
	TMI reference number		DM6269
	Version		Low Emiss
1	Wet CG from rear face of the block	mm	550
2	Wet CG up from crank shast centreline	mm	250
	Fuel consumption of the engine		
1	SFC @ 100% Load (with fan)	gm/bkw-hr	210.4
2	SFC @ 75% Load (with fan)	gm/bkw-hr	207.3
3	SFC @ 50% Load (with fan)	gm/bkw-hr	207.6
4	SFC @ 25% Load (with fan)	gm/bkw-hr	212.2
5	Fuel consumption @ 100% Load (Calculated)	LPH	132
6	Fuel consumption @ 75% Load (Calculated)	LPH	98
7	Fuel consumption @ 50% Load (Calculated)	LPH	65
8	Fuel consumption @ 25% Load (Calculated)	LPH	44
	Lub oil consumption of the engine		
1	Oil consumption as a % of full load fuel	%	0.10%
2	Lub oil consumption @ full load	g/kw-hr	0.21
3	Lub oil consumption @ 100% load	L/ Hr.	0.12
4	Oil density considered @ standard conditions	gms/lit	899
5	Lub oil change period	Hrs.	250
6	Recommended Lube Oil		CG / CH 4
	Heat Rejection details		
1	Heat rejection to coolant **	kW	155
2	Heat rejection to atmosphere **	kW	85
3	Heat rejection to exhaust **	kW	525
4	Heat that can be recovered from exhaust **	kW	311
5	Heat rejection to the lub oil **	kW	71
6	Heat rejection to aftercooler **	kW	123 (from A/C)

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

	Technical particulars of C-18 (Generator set package)		
	General: KVA rating 0.8/ 50 Hz	Genset KVA	600
	Cummins engine model		C 18
	Inlet manifold pressure		
	Model		Low Emiss
7	Fuel LHV	kW	1328
8	Fuel HHV	kW	1415
	Deration details		
1	Deration of the engine - Altitude @normal temp.	M	200
2	Deration of the engine - Altitude (@50 deg C	M	—
3	Deration of the engine - Humidity		Nil
	Air intake system		
1	Air intake restriction - with clean element	kPa	3.7
2	Air intake restriction - with dirty element	kPa	7.5
3	Filtration efficiency	%	99.5
4	Intake manifold temperature ** (+/- 10%)	Deg. C	46.1
5	Intake manifold pressure (+/- 10%)	kPa	232.4
6	Combustion air inlet flow rate (+/- 5%)	CFM	1458
7	Combustion air inlet flow rate (+/- 5%)	M3/Min.	41.3
	Fuel system		
1	Fuel system type		EUI
2	Filter type		Spin on
3	Filtration capacity (particle size)	Microns	2
4	Fuel Filter change period	Hours	250
5	Fuel Transfer Pump Type (Mechanical Lift/Feed)		Gear
6	Priming pump type		Manual
7	Fuel supply line restriction (Max. Allowable)	kPa	30
8	Fuel Flow to transfer pump	LPH	370.2

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

	Technical specifications of C-18 (Generator) Genset Engine		
	Description KVA rating of Generator Set		KVA	600
	Engine Model			C18
	TM reference number			3408396
	Version			2 Low Emiss
9	Fuel return line restriction (Max. Allowable)	kPa	27
10	Fuel flow (return line)	LPH	261.9
11	Fuel filter change recommended (Check gauge)	Hours	250 (by gauge)
12	Fuel Transfer Pump Flow (Max.)	lph	As above
13	Fuel Transfer Pump Pressure (Min)	kPa/psi	621
14	Max. lift of fuel transfer pump	ft	2.21 (w/o pr p'
	Lubrication System		
1	Refill volume with filter change	L	38
2	Lube oil system capacity (Total with filters)	L	38
3	Sump Capacity - Low Mark Level	L	26
4	Sump Capacity - High Mark Level	L	32
5	Lube oil pump flow	LPS	2.9
6	Oil temp. - Normal	Deg. C	95
7	Oil temp. - max.	Deg. C	113 (max)
8	Oil pressure - rated speed (Range)	kPa	588
9	Oil pressure - low idle (Range)	kPa	544
10	Filter type		Ful-FL S-0
11	Filter type		Spin ON
12	Filtration capacity in microns	Microns	15
13	Filteration System		Full Flow
14	Lube Oil Change period	Hours	250
15	Lube oil Filter change period	Hours	250
16	Crankcase ventilation type		Atmosphere
17	Oil cooler type		Shell & Tube
	Starting System		

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

	Technical particulars of C-18 (Generator set engine)		
	Description / KVA Rating 0.8pf, 50Hz		600 KVA
	Engine Model		
	TM Reference number		
	Version		Low Emissions
1	System voltage	V DC	24
2	Battery capacity for 90 sec.cranking @0°C (Min)	CCA	730
3	No. of starter motors provided	No.	1
4	Rating of Starter Motor	KW	9
5	Battery charging alternator capacity	Amps.	45 A
6	Min Cranking speed reqd. for start	rpm	115
	Safeties and Instrumentation		
1	Fuel Shutoff Solenoid (Standard)	Type	Electronic
2	Low Lube Oil Pressure Shutoff (+/-5%)	kPa	Yes / 138
3	High Water Temperature Shutoff (+/-2°C)	°C	Yes / 107
4	Overspeed Trip	rpm	?? / 1770
5	Crank Termination Signal (Contact only)	rpm	?? / 400
6	Lube Oil Pressure Gauge		EMCP II+
7	Water Temperature Gauge		EMCP II+
8	Fuel Pressure Gauge		Yes
9	Tachometer (with non-contact magnetic pickup)		EMCP II+
10	Air Inlet Restriction (Vacuum) Indicator		Yes
11	Service Hour Meter (SMU/Service Meter Unit)		EMCP II+
	Jacket Water System		
1	Engine jacket water coolant capacity	L	20.8
2	System Coolant Pressure	PSI	9
		kPa	62
3	Coolant outlet temp. max. allowed	Deg. C	104
4	Coolant Pump Flow	LPS	6.1
5	Start to open temp. - thermostat	Deg. C	88

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

	Technical particulars of C-18 (Generator Set package)		
	Description / KVA Rating 0.8 pf, 50 Hz	KVA	600
	Engine Model		C-18
	TMI reference number		DM 7398
	Version		Low Emiss.
6	Fully open temp - thermostat	Deg. C	98
7	Min. coolant fill rate (if applicable)	LPM	19
8	Min. coolant expansion space (% of sys.capacity)	%	15
	Engine mounted Radiator details		
1	Coolant capacity of radiator	Liters	50.5
2	Ambient capability of the radiator	Deg C	50+
3	Air Flow across Radiator	m^3/min	852
4	Radiator Face area	m^2	1.75
5	Fins per Inch		15
6	Fan Diameter	inches	38
7	Fan Power	KW	14
8	Radiator Fan type		Pusher (Blower)
9	No. of blades		9
10	Radiator Fan Drive ratio		0.8 : 1
11	Radiator cap pressure	PSI	10
12	Weight of radiator (Dry)	kg	200
	EXHAUST EMISSIONS (Rated Speed & nominal)		
1	Wet Exhaust mass	Kg/hr	3038
2	Wet Exhaust mass flow (@ 372deg C stack temp)	m^3/min	118.2
3	Total NOx (as NO2) (@ 100% load factor)	g/kw-hr	2.98
4	Total CO (@ 100% load factor)	g/kw-hr	1.25
5	Total HC (@ 100% load factor)	g/kw-hr	0.04
6	Particulate Matter (@ 100% load factor)	g/kw-hr	0.08
7	Oxygen in Exhaust (as %) (@ 100% load factor)	%	9.6

Table1 Technical specifications of C-18 DITA (600 KVA) Genset Engine (ctd.)

Technical Particulars of C-18 (Generator set package)			
Description : KVA Rating 0.8 p.f. 50 hz		KVA. TO kw	600 480
Engine Model			C 18
TMI reference number			DM7699
Version			Low Emiss
Mounting System			
1	Flywheel housing	SAE#	"0"
2	Flywheel dimension		
	- Diameter	mm	571.55
	- Width	mm	124.8
	- No. of teeth	No.	136
3	Type of coupling		Flexible
Governing System			
1	Type of governor		Cat ADEM III
2	Class of Governor		A1
3	Steady State Speed Band of regulation	%	+/- 0.25%
4	Droop (+/-1%)	%	0 to 10% (var)
5	Temporary & Permanent variation		BS5514,Class A1
6	Cyclic variation (see Steady State Speed Band)	cy./sec	<1/50

Note:

*- These ratings also apply at ISO3046/1, BS5514 & DIN 6271 standard consitions.

**- Performance data are at SAE 11349 standard conditions.

***- Involves conversion to ETSO Fuel Solenoid

****- Fuel density considered 838.8 gms/litre

2.2 Engine Specifications – 3412-725KVA Genset Engine

Table2 Technical specifications of 3412- DISTA (725 KVA) Genset Engine

	3412B DISTA 725 kVA Engine Details		
	Engine Model	**Units**	**3412 DITA GP-3**
1	Power rating of the engine @ 1500 rpm	EkW	580
2	Gross Engine BHP	BHP	849
3	Gross Engine KW	kW	633.4
4	Typical Alternator Efficiency @ 100% load	%	95.2%
5	Power Drawn from engine w/o radiator fan	BKW	609.2
6	Radiator fan power	kW	20
7	Length(Engine Alone W/O Cooling System)	mm	2154.6
8	Width(Engine Alone)	mm	2078
9	Height(Engine Alone)	mm	1999.2
10	Total dry weight of engine (w/o cooling system)	kg	2141
11	Dry Weight of Radiator	kg	280
12	Package Length - Radiator Cooled With Acoustic	mm	Ref acoustic catalog
13	Package Width - Radiator Cooled With Acoustic	mm	
14	Package Height - Radiator Cooled With Acoustic	mm	
15	Total wet weight of Package with Acoustic	kg	
16	Wet weight of the radiator	kg	Weight included in Total wet weight
17	No. of Cylinders	No.	12
18	Bore & Stroke	mm	137 x 152
19	Displacement	L	27
20	Compression ratio	No.	13 : 1
21	BMEP of the engine	kPa	1872
22	Direction of rotation (SAE Std.) - FW End		CCW
23	'V' angle	Deg.	65
24	Firing order		1-4-9-8-5-2-11-10-3-6-7-12
25	Aspiration of engine		STA
26	Piston speed of engine	m/sec	7.6
27	Max. overspeed allowed (Trip set at)	rpm	1770
28	Max. allowable static bending moment at the rear face of flywheel housing	Nm	1356
29	Friction horse power lost	kW	63
30	Mechanical efficiency of the engine	%	91%
31	Thermal efficiency of the engine (Considering HHV)	%	40%
32	Reference Standards for Engines *		SAE J1349 *
1	Exhaust system back pressure (max.)	kPa	6.7
2	Diameter of engine exhaust outlet (inside)	mm	
3	Muffler/Silencer Restriction(Residential) Ps	"H20	
4	Exhaust flange details		

Table2 Technical specifications of 3412- DISTA (725 KVA) Genset Engine (ctd..)

	3412B DISTA 725 KVA Engine Details			
	Engine Model:		**Unit**	**3412 DITA-GP-3**
	- No. of holes		No.	
	- Dia. of holes		mm	
	- PCD		mm	
	- No. of exhaust outlets		Nos	
5	No. of exhaust outlets on engine		No.	2
6	Max. weight of exhaust system on engine		kg	Muffler Mounted on Enclosure
7	No. of residential silencers supplied		No.	4
8	Noise reduction silencer(s)-Typical		dB(A)	Meets CPCB Norms
9	Weight of muffler(Horizontal/Vertical mtg.allowed)		kg	Muffler Mounted on Enclosure
10	Exhaust gas flow rate ** (+/- 6%)		CFM	4427.874
11	Exhaust gas flow rate ** (+/- 6%)		M3/Min	125.4
12	Exhaust gas temp.(stack) ** (+/- 8%)		Deg. C	534
	LUBRIC CONSUMPTION OF THE ENGINE			
1	Lub oil consumption @ 100% load		L/ Hr.	0.343
2	Lub oil consumption @ 75% load		L/ Hr.	0.257
3	Lub oil consumption @ 50% load		L/ Hr.	0.171
4	Lub oil consumption @ 25% load		L/ Hr.	0.086
5	Lub oil change period		Hrs.	250
6	Recommended Lube Oil			API CF4 15W 40
	HEAT REJECTION DETAILS (+/- 5%)			
1	Heat rejection to coolant **		kW	365
2	Heat rejection to atmosphere **		kW	95
3	Heat rejection to exhaust **		kW	571
4	Heat that can be recovered from exhaust **		kW	333
5	Heat rejection to the lub oil **		kW	49
6	Heat rejection to aftercooler **		kW	66
7	Fuel LHV		kW	1563
8	Fuel HHV		kW	1664
	DERATION DETAILS			
1	Deration of the engine - Altitude @normal temp.		M	750
2	Deration of the engine - Humidity			NIL
	AIR INLET SYSTEM			
1	Air intake restriction - with clean element		kPa	3.7
2	Air intake restriction - with dirty element		kPa	7.5
3	Filtration capacity in microns		Microns	5
4	Intake manifold temperature ** (+/- 10%)		Deg. C	89
5	Intake manifold pressure (+/- 10%)		kPa	213
6	Combustion air inlet flow rate (+/- 5%)		CFM	1580

Table2 Technical specifications of 3412- DISTA (725 KVA) Genset Engine (ctd..)

	3412B DISTA 725KVA Engine Details		
	Engine Model	**Unit**	**3412/DITA GP3**
7	Combustion air inlet flow rate (+/- 5%)	M3/Min.	44.2
	FUEL SYSTEM		
1	Fuel system type		Cat New Scroll FIP
2	Filter type		Canister, Spin-on
3	Filtration capacity (particle size)	Microns	5
4	Fuel Transfer Pump Type (Mechanical Lift/Feed)		Gear
5	Priming pump type		Manual
6	Fuel supply line restriction (Max. Allowable)	kPa	30
7	Fuel return line restriction (Max. Allowable)	kPa	27
8	Fuel filter change recommended (Check gauge)	Hours	250 to 500
9	Fuel Transfer Pump Flow (Max.)	lph	193
10	Fuel Transfer Pump Pressure (Min)	kPa/psi	172/25
11	Max. lift of fuel transfer pump	ft	7
	Fuel Consumption (lph)		
1	@100% Load	lph	151.49
2	@90% Load	lph	137.36
3	@80% Load	lph	123.02
4	@75% Load	lph	115.88
5	@70% Load	lph	108.73
6	@60% Load	lph	94.99
7	@50% Load	lph	81.34
8	@40% Load	lph	68.01
9	@30% Load	lph	54.40
10	@25% Load	lph	47.51
11	@20% Load	lph	40.56
12	@10% Load	lph	27.01
13	Density of fuel considered	kg/l	0.85
14	Tolerance as per ISO 3046 (0-5%)		0 to +5%
	Specific Fuel Consumption		
1	@100% Load	g/bkw-hr	207.8
2	@90% Load	g/bkw-hr	206.9
3	@80% Load	g/bkw-hr	209.7
4	@75% Load	g/bkw-hr	210.2
5	@70% Load	g/bkw-hr	210.7
6	@60% Load	g/bkw-hr	213.1
7	@50% Load	g/bkw-hr	216.3
8	@40% Load	g/bkw-hr	220.8
9	@30% Load	g/bkw-hr	227.8
10	@25% Load	g/bkw-hr	233.1
11	@20% Load	g/bkw-hr	240.6

Table2 Technical specifications of 3412- DISTA (725 KVA) Genset Engine (ctd..)

	3412C DISTA 725KVA Engine Details		
	Engine Model	**Unit**	**3412 DITAGP 3 G**
12	@10% Load	g/bkw-hr	278.4
	LUB OIL SYSTEM		
1	Refill volume with filter change	L	126.4
2	Lube oil system capacity (Total with filters)	L	128
3	Sump Capacity - Low Mark Level	L	46
4	Sump Capacity - High Mark Level	L	59
5	Sump angle - Front down	Deg. C	36
6	Sump angle - Front up	Deg. C	22
7	Sump angle - Side to side	Deg. C	34
8	Oil temp. - max.	Deg. C	105 - 120
9	Oil pressure - rated speed (Range)	kPa	275-600
10	Oil pressure - low idle (Range)	kPa	275-600
11	Oil Pressure - Full Load (Typical)	kPa	422
12	Oil Pressure - Low Idle (Typical)	kPa	399
13	Filter type		Paper
			Canister,Spin-on
14	Filtration capacity in microns	Microns	15
15	Filteration System		Full flow
16	Crankcase ventilation type		Atmosphere
17	Oil cooler type		Tube
	STARTING SYSTEM		
1	System voltage	V DC	24
2	Battery capacity for 90 sec.cranking @0°C (Min)	CCA	870
3	No. of starter motors provided	No.	1
4	Rating of Starter Motor	KW	9.6
5	Battery charging alternator capacity	Amps.	35A
	SAFETY & INSTRUMENTATION		
1	Fuel Shutoff Solenoid (Standard)	Type	ETSO
2	Low Lube Oil Pressure Shutoff (+/-5%)	kPa	Yes/138
3	High Water Temperature Shutoff (+/-2°C)	°C	Yes/107
4	Overspeed Trip	rpm	Yes/1770
5	Crank Termination Signal (Contact only)	rpm	Yes/400
6	Lube Oil Pressure Gauge		Analog
7	Water Temperature Gauge		Analog
8	Battery Charging Ammeter		Electric
9	Fuel Pressure Gauge		Analog
10	Tachometer (with non-contact magnetic pickup)		Digital
11	Air Inlet Restriction (Vacuum) Indicator		Provided
12	Service Hour Meter (SMU/Service Meter Unit)		Electric
	JACKET WATER SYSTEM		

Table2 Technical specifications of 3412- DISTA (725 KVA) Genset Engine (ctd..)

	3412B DISTA 725KVA Engine Details	Units	3412 DITA-GP-3
	Engine Model		
1	Engine jacket water coolant capacity	L	60.6
2	System Coolant Pressure	PSI	7
		kPa	48.265
3	Coolant outlet temp. max. allowed	Deg. C	107
4	Coolant inlet temp. min. allowed	Deg. C	71
5	Max. Coolant Frictional head	M	5
6	Coolant Pump Flow	LPM	530
7	Start to open temp. - thermostat	Deg. C	80 - 86
8	Fully open temp - thermostat	Deg. C	90 - 94
9	Min. coolant fill rate (if applicable)	LPM	25
10	Min. coolant expansion space (% of sys.capacity)	%	15
	HEAT EXCHANGER DETAILS		
1	Heat exchanger capacity - Jacket Water	L	
2	Fluid flow rate - raw water side	LPM	
3	No. passes made	No.	
4	Max. Raw water inlet pressure (at HEX inlet)	kg/ cm2	
5	Weight of heat exchanger (Dry)	kg	
6	Raw water IN / OUT Diameter at HEX Inlet	Inch	
7	Temperature IN / OUT	deg C	
8	Pressure drop max.	psi	
9	Raw water pressure	Kg/ cm2	
	ENGINE MOUNTED RADIATOR DETAILS		
1	Coolant capacity of radiator	L	100
2	Ambient capability of the radiator	Deg C	50+
3	Air Flow across Radiator	m3/min	1260
4	Fan Diameter	inches	54
5	Fan Power	KW	22
6	Air Flow Restriction (after radiator)	kPa	0.06
7	Radiator cap pressure	PSI	8
8	Weight of radiator (Dry)	kg	Inluded in Package
	EXHAUST EXPANSION		
	MUFFLER DETAILS (N/A)		
	MOUNTING SYSTEM		
1	Flywheel housing	SAE#	"0"
2	Flywheel dimension		
	- Diameter	mm	571.55
	- Width	mm	124.8
	- No. of teeth	No.	136
3	Type of coupling (for 2 bearing)		Flexible
	GOVERNING SYSTEM		

Table2 Technical specifications of 3412- DISTA (725 KVA) Genset Engine (ctd..)

	3412B DISTA 725kVA Engine Details	Unit	3412 DITA GP-3*
	Engine Model		
1	Type of governor		Electronic ECM
2	Class of Governor		A1
3	Steady State Speed Band of regulation	%	+/- 0.25%
4	Droop (+/-1%)	%	0 - 10%
5	Temporary & Permanent variation		BS5514, Class A1
6	Cyclic variation (see Steady State Speed Band)	cy./sec	< 1/50
	Note:		
*- These ratings also apply at ISO3046/1, BS5514 & DIN 6271 standard conditions.			
**- Performance data are at SAE J1349 standard conditions.			
***- Involves conversion to ETSO Fuel Solenoid			

2.3 Performance Specifications C-18 DITA 600 KVA Genset Engine

Table3. Test specifications of C-18 DITA (600 KVA) Genset Engine

CATERPILLAR®   C18 ACERT ™   INDUSTRIAL ENGINE
522 bkW (700 bhp)

Performance Data

WELL SER - EM0018-00

Aftercooler Temperature 49.0 °C (120.0 °F)

English

Engine Speed rpm	Engine Power hp	BSFC lb/hp-h	Fuel Rate gph	Intake Mainfold Temp °F	Intake Manf Press in-hg	Intake Air Flow cfm	Exh Manif Temp °F	Exh Stk Temp °F	Exh Gas Flow cfm	Engine Torque lb ft	Engine BMEP psi
2100	700	0.375	37.5	121.0	62.8	1,730.4	1,246	943	4,749.8	1,751	239
1900	700	0.357	35.7	118.0	62	1,596.2	1,240	947	4,393.1	1,935	264
1700	692	0.356	35.2	117.0	63.2	1,483.2	1,273	991	4,220.1	2,138	291
1600	677	0.341	33.0	112.0	59	1,349	1,281	1,005	3,877.6	2,223	303
1400	629	0.346	31.0	104.0	55.5	1,161.9	1,346	1,083	3,527.9	2,359	322
1000	306	0.335	14.7	85.0	18	473.2	1,235	1,100	1,458.5	1,608	219

Heat Rejection Data

Engine Speed rpm	Engine Power hp	Rej to JW Btu/min	Rej to Atmos Btu/min	Rej to Exh Btu/min	From Aft Clr Btu/min
2100	700	9156	7393	32871	8019
1900	700	8644	7052	30653	7052
1700	692	8985	5971	30084	6597
1600	677	8474	6369	28037	5687
1400	629	8303	5630	26501	4891
1000	306	5005	2787	11260	910

CHAPTER 3.DATA & ANALYSIS OF C-18 GENSET ENGINE

Table 4.Test data for C-18 (600 KVA) Genset Engine

Condition	Time	Cell Temperature Thermometer	Engine Speed	Torque	Power	Exhaust Stack Temperature	Air Filter Temperature (Near Side)	Air Filter Temperature (Far Side)	Difference in Air Filter Temperature
	min	Deg C	rpm	N-m	KW	Deg C	Deg C	Deg C	Deg C
	0.00	25	1621	370	62.8	52.5	27	27	0
High Idle	1.00	28	1618	370	62.69	65	28	27	1
	2.00	30	1620	369	62.59	70.5	29	28	1
	3.00	31	1620	368	62.43	86	30	28	2
Full Load Statics	4.00	31	1495	3351	524.6	84	29	28	1
	5.00	31	1492	3345	522.6	83	29	28	1
High Idle	6.00	40	1620	370	62.76	155	46	33	13
	7.00	47	1141	21	2.509	185	52	36	16
	8.00	55	1141	21	2.509	215	56	42	14
	9.00	49	1141	21	2.509	201.5	51	37	14
	10.00	44	1141	21	2.509	163.5	33	30	3
	11.00	37	1140	21	2.507	145	30	29	1
Low Idle	12.00	33	1141	20	2.39	116	28	27	1
	13.00	32	1141	20	2.39	109	25	24	1
	14.00	30	1141	20	2.39	102.5	24	23	1
	15.00	29	1141	20	2.39	92	27	26	1
Re loaded condition	16.00	28	1620	371	62.93	81.5	24	24	0
Full Load Statics	17.00	29	1486	3518	547.4	100	32	29	3
	18.00	39	1485	3529	548.8	154.5	37	37	0
Torque Check	19.00	52	1396	3985	582.5	205	58	38	20
Re loaded condition	20.00	56	1621	374	63.48	217.5	61	47	14
Full Load Statics	21.00	59	1480	3500	542.4	248	69	52	17
	22.00	63	1485	3496	543.6	229.5	47	39	8

orque check	23.00	45.5	1395	4007	585.3	214.5	54	32	22
	24.00	64	1264	23	3.044	261	54	51	3
	25.00	64	1260	23	3.035	262.5	64	56	8
w Idle	26.00	49	1199	22	2.762	235	58	42	16
	27.00	48	1200	22	2.764	208	47	38	9
	28.00	39	1200	22	2.764	171	40	37	3
	29.00	37							
	30.00	34.8							
	31.00	33	Cell Cooling due to Exhaust fan						
ngine Shut Down	32.00	32							
	33.00	31							
	34.00	30.5							
	35.00	30							

Values considered for calculations

3.2 Heat Balance Calculations for C – 18 (600 KVA):

- **Heat Source:**

    1. Heat input by Fuel = Calorific value of Fuel (Low Sulphur Diesel)

        x   Fuel Consumption rate

    Calorific Value = 40,183 kJ/kg

    Fuel Consumption rate = 2.154 kg/min=0.0359 kg/s

    Heat input = 40183 x 0.0359 = 1442 kJ/s= <u>1442 Kw</u>

- **Heat rejections:**

  1. Brake Power obtained (maximum), kW = (Torque x Speed)/ 9550

     Torque = 4007 Nm

     Speed = 1495 rpm

     Brake Power = (1495 x 4007)/9550 = <u>585.31 kW</u>

  2. Heat lost to exhaust gases = $m_{ex} C_p \Delta T$

     m_{ex} = mass flow rate of exhaust gases = 0.8562 kg/s *

     C_p =Specific heat of exhaust gases = 1.100536 kJ/kg K (@537 Deg C)

     ΔT=Exhaust gas temp~inlet air temp=537-46=491Deg C*

     Heat lost to exhaust gases = 0.8562 x 1.100536 x 491 = <u>462.9 kW</u>

  3. Heat removed by cooling water = $m_w C_p \Delta T$

     Heat removed by cooling water = <u>155 KW</u> *

4. Heat lost to the atmosphere = $(m_a C_p \Delta T)/t$

   Mass of air inside cell, ma = volume of cell x density of air @ cell

   temperature= 234 m^3 x 1.11 kg/ m^3 = 260 kg

   C_p = Specific heat of air = 1.006 kJ/kg K

   Δ T= Rise in cell temperature = 64~45.5= 18.5 Deg C

   t= time = 1 min = 60 s

   Heat lost to the atmosphere =(260 x 18.5 x 1.006)/60 = <u>81.878 kW</u>

5. Heat removed by FD exhaust fan (after engine shutdown) = $(m_a C_p \Delta T)/t$

   Mass of air inside cell, m_a = volume of cell x density of air @ cell

   Temperature = 234 m^3 x 1.11 kg/ m^3 = 260 kg

   C_p = Specific heat of air = 1.006 kJ/kg K

   Δ T= Rise in cell temperature = 37~30 = 7 Deg C

   t= time = 6 min = 360 s

   Heat lost to the atmosphere =(260 x 7 x 1.006)/360 = <u>5.225 kW</u>

6. Other losses = (Fuel heat input ~ Heat rejections accounted)

= (1442 – (585.31+462.9+155+81.878+5.224))

= 151.69 kW

Heat values:

Table5. Heat values for C-18 (600 KVA) Genset Engine

S.no	Heat Source	Observed (@100 % load)	TMI details (@ 100 % load)	Calorific value	Heat	
		g/min	g/min	kJ/kg	Observed KW	TMI KW
1.	Fuel	2,154	1,845.1	40,183	1442	1235.7
		Heat Rejection				
		Torque (Nm)	Speed (RPM)	Power (KW)		
1.	Brake power	4007	1395	585.31		
		Change in Temperature (Deg C)	Mass (kg/s)	Specific heat (kJ/kg)	Heat Removed (KW)	
2.	Heat lost to exhaust gases	491	0.8562(flow rate)*	1.100536	462.9	
3.	Heat removed by Cooling water	10	3.7 (flow rate)*	4.186	155 *	
4.	Heat lost to atmosphere	18.5	260 kg/s	1.006	81.878	
5.	Heat removed by FD fan	7	260 kg/s	1.0059	5.224	
6.	Other losses	-	-	-	151.69	

Data obtained from Technical Marketing Information (TMI)

Table 6.Heat Balance Sheet for C-18 (600 KVA) Genset Engine

Heat Balance Sheet for C-18 (600 KVA) Genset Engine			
S.no		Heat in KW	Heat in %
1.	Heat absorbed in Brake Power	585.31	40.59
2.	Heat rejected in Cooling Water	155	10.75
3.	Heat carried away by Exhaust Gases	462.90	32.10
4.	Heat lost to Atmosphere	81.88	5.68
5.	Heat removed by ventilation fan	5.22	0.36
6.	Other Losses	151.69	10.51
7.	Total heat (Fuel)	1442	100

3.3 Test Cell Heat Sources:

In the test cell, the engine is considered as the major source of heat and the heat radiated from other sources such as fuel lines, fans, lighting etc are negligible in comparison. Therefore, the forced ventilation requirements are designed for the heat input into the cell from the engine.

Heat input into the cell by the engine=(heat lost to atmosphere + heat removed by

Ventilation fan)

$$= (81.878 + 5.22) = 87.103 \text{ kW}$$

Heat input into the cell by the engine = 87.103 kW

3.4 Combustion Air Requirements:

Quantity of air required for combustion (@ 100 % Load) = 1,458.5 CFM = 41.3 m^3/min *

3.5 C-18 Genset Engine Air Filters Differential heating:

During the testing of C-18 Engines, there was an observed imbalance of the surface temperatures of the air filters. This showed an increased surface temperature on the air filter on the near side to control cabin. The difference had a maximum value of 22 Deg C. This localized excessive heating of this intake resulted in decreased density of the air taken in on the turbocharger's compressor side. This results in an insufficient mass of air being fed by the turbo charger to its respective air intake manifold. This in turn reduces the volumetric efficiency of the respective 3 cylinders resulting in a reduction of power at rated speed.

Causes:

A manual inspection of C-18 engines loaded onto test rig was conducted to identify the causes of this phenomenon. It was observed that an "elbow" pipe connecting the test cell exhaust stack to the engine exhaust passed over the air filter under scrutiny. The heat radiated from this elbow due to the flow of exhaust gases was identified to be the main cause of this excessive heating. This inference was reflected in the readings tabulated above in Table 3 and Fig.1. The largest difference in temperature was found to occur during High Idle and Full Load states of the engine, when the flow of exhaust gases through the connecting elbow is maximum. Thus, the direct cause of the differential heating of the air filters was found to be the positioning of the elbow pipe over the near side air filter.

Remedy:

A quick and effective solution to this anomaly is to turn the elbow pipe by 90 degrees about the vertical axis. This makes the elbow travel across the width of the engine rather than over the air filter as shown by the crude diagram Fig.1. It is then connected to the existing exhaust stack through an additional metal hosing.
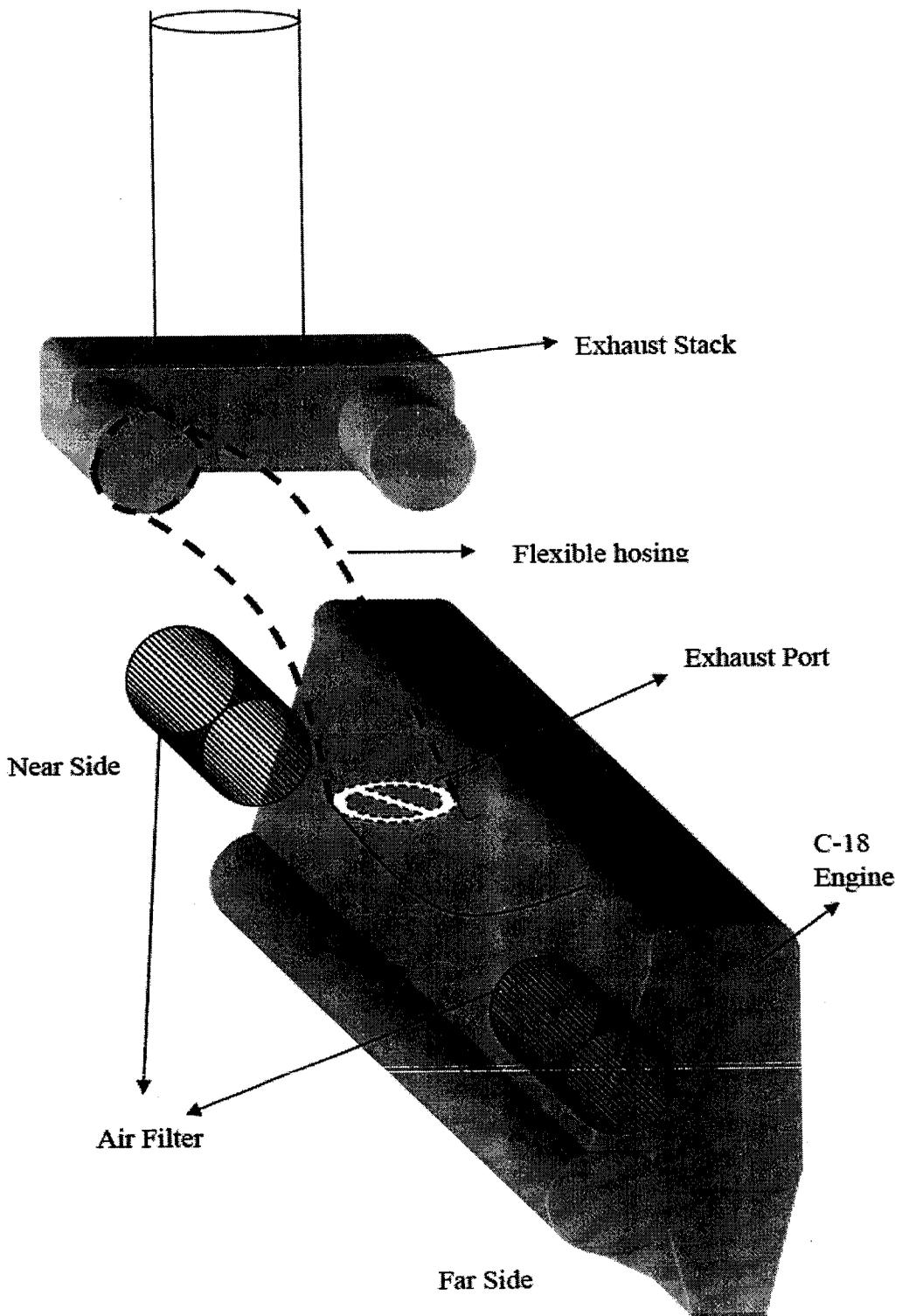
Exhaust Stack

Flexible hosing

Exhaust Port

Near Side

C-18 Engine

Air Filter

Far Side
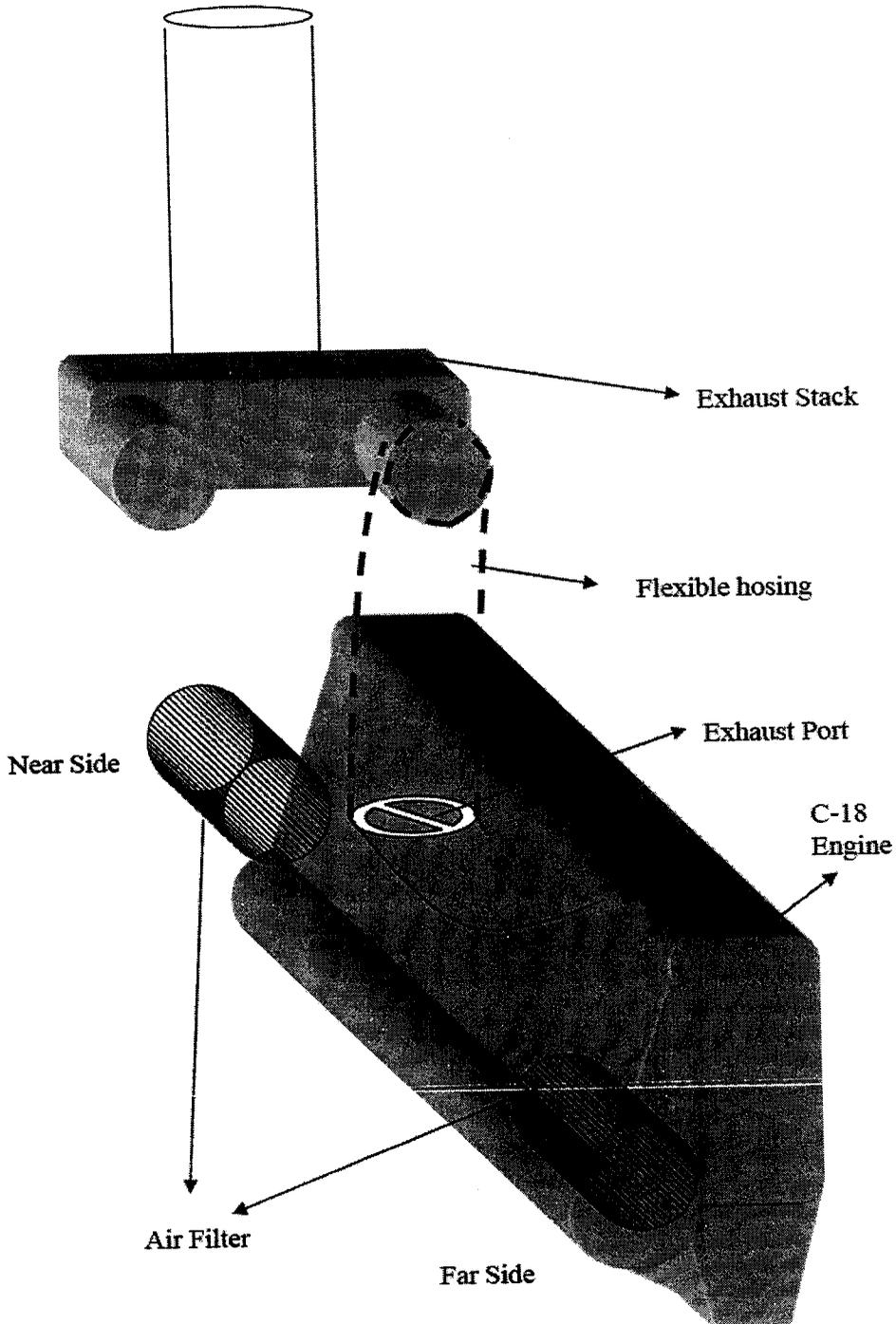
Fig.1. Existing Layout of C- 18 Exhaust Stack

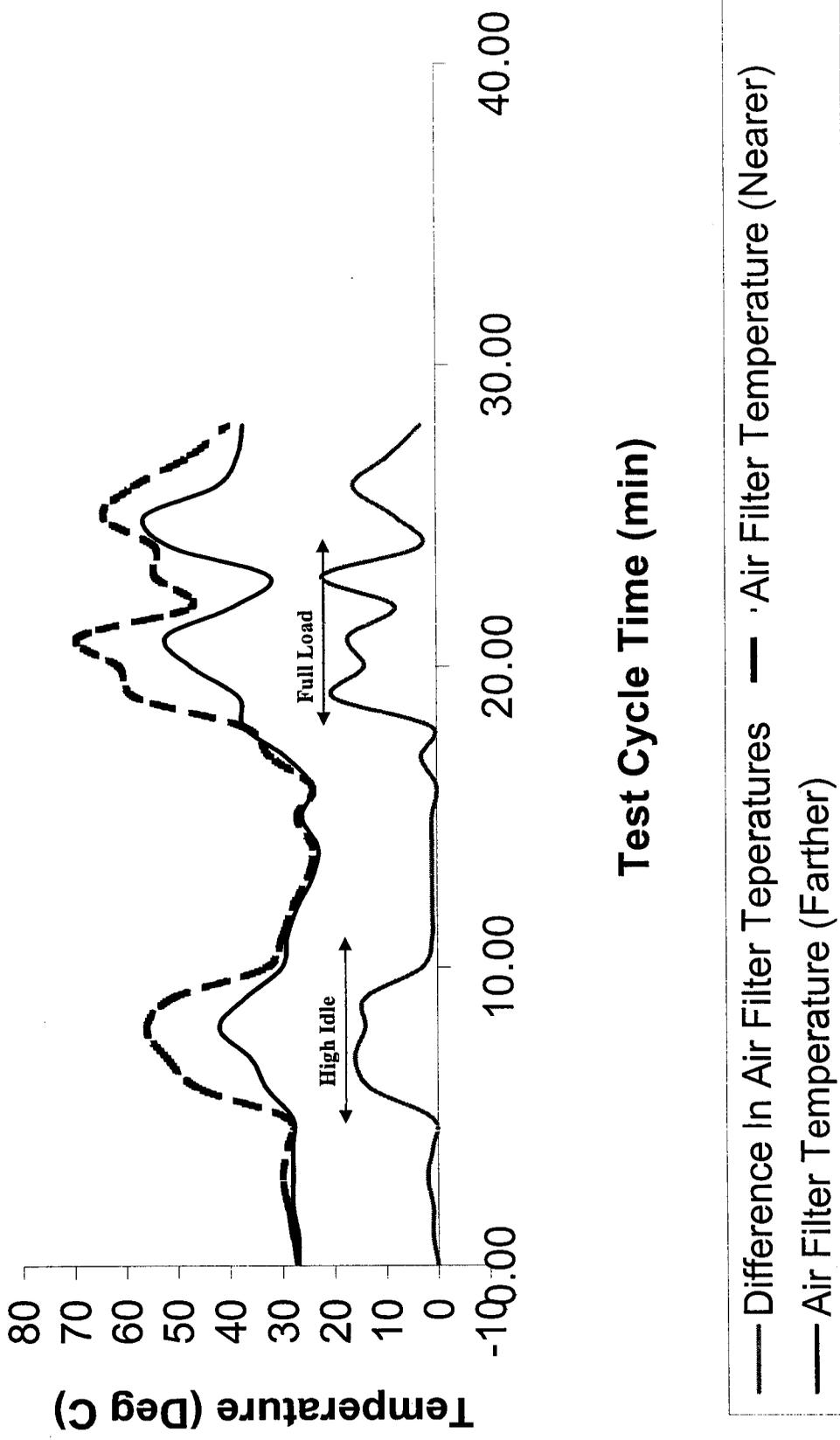Fig.2. Proposed Layout of C- 18 Exhaust Stack

Fig.3.*Differential Heating of Air filters in C-18 Genset Engine*

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CHAPTER 4.DATA & ANALYSIS OF 3412 -725 KVA GENSET ENGINE

4.1 Data for 3412-DITA (725 KVA) Engine Test Cycle in Test CELL III

Table 7.Test data for 3412 DITA (725 KVA) Genset Engine

Condition	Time	Cell temperature	Speed	Torque	Power	Exhaust Stack Temperature	Air Filter (Left)	Air Filter (Right)
	min	Deg C	rpm	Nm	kW	Deg C	Deg C	Deg C
	0.00	24.5	1612	1100	185.6754	43	24	24
	2.00	25	1615	1106	187.0356	63	25	25
Pre Loaded	4.00	25	1610	1105	186.288	90.5	26	25
	6.00	25.2	1610	1100	185.445	100	26	26
	8.00	25.2	1613	711	120.0883	99	26	26
Pre Loaded 91%	10.00	25.5	1547	692	112.0968	138.5	26	26
	12.00	25.5	1546	695	112.5099	148	26	26
Full Load Statics	14.00	25.8	1550	3646	591.7592	171	28	28
	16.00	26	1551	3624	588.568	213	28	28
Pre Load 79 %	18.00	26	1546	695	112.5099	215.5	29	29
	20.00	26	1546	86	13.92209	148.5	24	24
	22.00	25.5	1547	87	14.09309	51	23	23
Washing	24.00	25.2	1547	87	14.09309	135	23	23
	26.00	25.2	1547	87	14.09309	128.5	24	24
	28.00	25.2	1546	86	13.92209	141	25	25
	30.00	25.2	1500	4403	691.5707	178	26	26
Full Load Statics	32.00	25.8	1520	4403	700.7916	194	28	28
	34.00	26	1522	4403	701.7137	198	28	24
Pre Load 79 %	36.00	26.2	1546	650	105.2251	200	27	26
Full Load Statics	38.00	26.2	1503	4428	696.8884	218	28	27

	40.00	26.5	1500	4425	695.0262	225	29	29
	42.00	27	1547	88	14.25508	205	32	32
Idle	44.00	28	1545	88	14.23665	171	31	31
	46.00	27	1547	88	14.25508	164.5	31	31

Values considered for calculations

4.2 Heat Balance Calculations for 3412 DITA (600 KVA):

- **Heat Source:**

    1. Heat input by Fuel = Calorific value of Fuel (Low Sulphur Diesel)

    x   Fuel Consumption rate

    Calorific Value = 40,183 kJ/kg

    Fuel Consumption rate = 2.470 kg/min=0.04116kg/s

    Heat input = 40183 x 0.04116 = 1654.20 kJ/s= <u>1654.20 kW</u>

- **Heat rejections:**

    1. Brake Power obtained (maximum), kW = (Torque x Speed)/ 9550

    Torque = 4403 Nm

    Speed = 1522 rpm

    Brake Power = (1522 x 4403)/9550 = <u>701.7137 kW</u>

    2. Heat lost to exhaust gases = m_{ex} Cp ΔT

    m_{ex} = mass flow rate of exhaust gases = 0.9641 kg/s *

    C_p = Specific heat of exhaust gases = 1.100536 kJ/kg K

    ΔT=Exhaust gas temperature~inlet air temperature=537~89=448 Deg C*

    Heat lost to exhaust gases = 0.9641 x 1.100536 x 448= <u>475.31 kW</u>

3.Heat removed by cooling water = $m_w C_p \Delta T$

  Heat removed by cooling water = <u>365 KW</u> *

4.Heat lost to the atmosphere = $(m_a C_p \,? \,T)/t$

  Heat lost to the atmosphere = <u>95 kW</u>*

5.Other losses = (Fuel heat input ~ Heat rejections accounted)

  $$= (1654.2 - (701.7137 + 475.31 + 365 + 95))$$

  $$= \mathbf{17.1764 \ kW}$$

Heat values:

Table 8. Heat values for 3412 DITA (725 KVA) Genset Engine

S.no	Heat Source	Observed (@100 % load)	TMI details (@100 % load)	Calorific value	Heat	
		g/min	g/min	kJ/kg	Observed KW	TMI KW
1.	Fuel	2,470	2,141	40,183	1654.2	1434
		Heat Rejection				
		Torque (Nm)	Speed (RPM)	Power (KW)		
1.	Brake power	4403	1522	701.7136		
		Change in Temperature (Deg C)	Mass (kg/s)	Specific heat (kJ/kg)	Heat Removed (KW)	
2.	Heat lost to exhaust gases	448	0.9641(flow rate)*	1.100536	475.31	
3.	Heat removed by Cooling water	10	8.7 (flow rate)*	4.186	365 *	
4.	Heat lost to atmosphere	-	-	-	95*	
6.	Other losses	-	-	-	17.17	

Table 9.Heat Balance Sheet for 3412 DITA (725 KVA) Genset Engine

	Heat Balance Sheet for *3412 DITA (725 KVA)* Genset Engine		
S.no		Heat in KW	Heat in %
1.	Heat absorbed in Brake Power	701.7136	42.42
2.	Heat rejected in Cooling Water	365	22.06
3.	Heat carried away by Exhaust Gases	475.31	28.73
4.	Heat lost to Atmosphere	95	5.74
6.	Other Losses	17.18	1.03
7.	Total heat (Fuel)	1654.2	100

4.3 Test Cell heat sources:

Unlike the previously collected data, the heat input into the test cell is calculated from two major sources i.e. heat lost to the atmosphere and heat radiated from the exhaust stack.

Heat input into the cell by the engine

=(Heat lost to atmosphere + heat transfer from exhaust stack)

Heat lost to the atmosphere = 95 kW (from heat balance sheet)

Heat transfer from exhaust stack

= (Radiative heat transfer + convective heat transfer)

Radiative Heat transfer = $(e \times 5.77 \times A \times [(T_e/100)^4 - (T_a/100)^4)]) / 1000$ (kW)

Convective heat transfer by natural convection from a vertical surface in still air

$$= (1.9 \times A \times \Delta T^{1.25}) / 1000 \quad (kW)$$

Where,

e = Emissivity of exhaust stack material (Oxidized iron)=0.78

s =Stefan Boltzmann's Constant=5.670 400×10^{-11} kW·m^{-2}·K^{-4}

Te = Exhaust Stack Temperature = (225+273) = 498 K

Ta =Ambient Air temperature= (26.5 + 273) = 299.5 K

ΔT = (Te - Ta) = **198.5 K**

A= Area of exhaust stack = p x external diameter x height

= p x .206 x 5.0616 =**3.29 m^2**

Radiative Heat transfer = (0.78 x 5.77 x 3.29 x (615.05-80.46)) / 1000

= **7.915 kW**

Convective Heat transfer = (1.9 x 3.29 x (198.5)$^{1.25}$) / 1000 = **4.657 kW**

The convective heat transfer as mentioned is for still air conditions. However, there exist currents in the test cell produced due to the forced draught fans. The air velocity inside can be assumed to be **3 m/s** which causes the convective heat transfer to increase **four-fold** (Engine Test Cell Design , A.J.Martyr).

Heat input into the cell by the engine = 95+(7.915 +(4 x 4.657))= 121.55 kW

4.4 Combustion Air Requirements:

Quantity of air required for combustion (@ 100 % Load) = 1560 CFM = **44.19 m^3/min***

CHAPTER 5. VENTILATION SYSTEMS DESIGN

5.1 Ventilation & Induction Air Requirements for Test cell-I

The values calculated above present nominal values of heat input to the cell during test cycle of C-18 (600 KVA) and 3412 DITA (725 KVA). The maximum value of heat and induction air required is to be assumed for design of ventilation system and hence the values of 3412 DITA (725 KVA) Genset engine is taken into consideration.

Therefore, heat to be removed from test cell = 121.55 = **122 kW (Approx.)**

Induction Air Requirements = 44.19 m^3/min = **45 m^3/min = 0.75 m^3/s**

5.2 Design of ventilation system:

Total heat to be removed from the test cell by the ventilation system,(H)=122 kW

Air inlet temperature = 25 Deg C = 298 K (Atmospheric Air)

Air inlet Pressure (@ 1000m Elevation) = 92 kPa

Density of air at inlet (@92 kPa & 25 Deg C) = 1.046 kg/m^3

Specific heat of inlet air (@ 25 Deg C) = 1.005 kW/kg K

Let us assume a temperature rise of ventilation air, ΔT = 30 Deg C.

Then the required air flow rate ,Qa (m^3/s) is

Qa= Heat to be removed / (Density x Specific Heat x Temperature rise)

$\qquad$ = 122 / (1.046 x 1.005 x 30)

$\qquad$ = 3.868 m^3/s

$\qquad$ = 8197.5 cubic feet/min

The concept of air changes is a very important aspect of engine test cell ventilation. The number of air changes per hour is given by multiplying the air flow rate by 3600 and dividing it by the volume of the test cell.

Air Changes /hour = (Qa x 3600)/ volume of test cell

$$= (5.1368 \times 3600)/(\text{length x breadth x height})$$

$$= (18492.48)/(6.5 \times 4.8 \times 7.5)$$

$$= 59.5 = 60 \text{ cell air changes per hour.}$$

A ventilation system of 60 air changes is an acceptable air change number in an engine testing cell. (Engine Test Cell Design , A.J.Martyr)

Note: A temperature rise, ΔT=30 Deg is an accepted reasonable basis for design. Clearly, the higher the value of ΔT, the smaller the corresponding air flow. However, a reduction in air flow has two influences on general cell temperature: the higher the outlet temperature the higher the mean level in the cell, while a smaller air flow implies lower air velocities in the cell, calling for a greater temperature difference between cell surfaces and air for a given rate of heat transfer.

5.3 Exhaust Fan Design :

For a given flow rate, axial flow fans are more compact and are easily adapted to fit inside circular ducts. They are not sensitive to dust and are easy to install. They are very effective as spot fans and have a moderate efficiency around 65 to 75 %. So an axial fan has been chosen to provide the required ventilation in the test cell. The fan is to be mounted on the test cell ceiling with appropriate ducting and discharge hood. For the stated necessity , a manufacturer's catalogue has stated the above fan specifications :

EPC Fans , India td. (*http://www.epcfan.com/*)

Diameter : 610 mm

Speed : 1420 RPM

Static Pressure : 99 kPa

Motor Rating : 0.75 kW

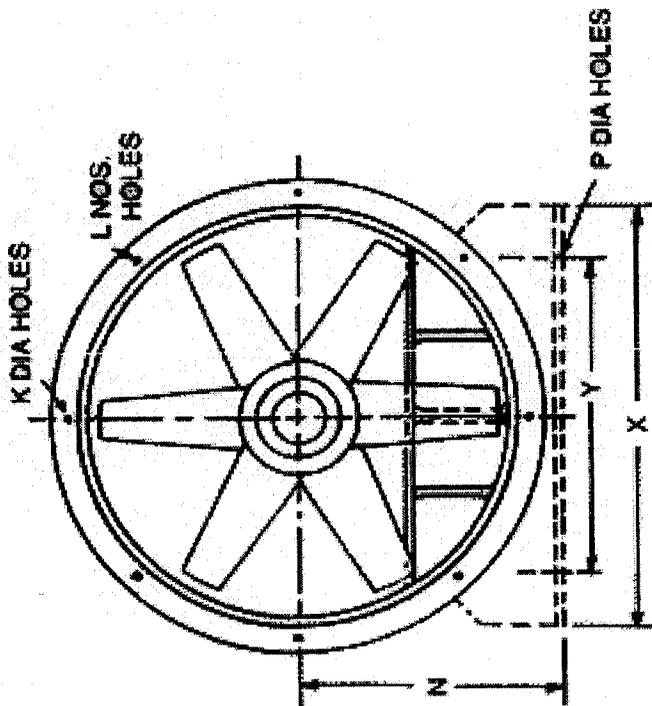Volume Flow Rate : 8700 CFM
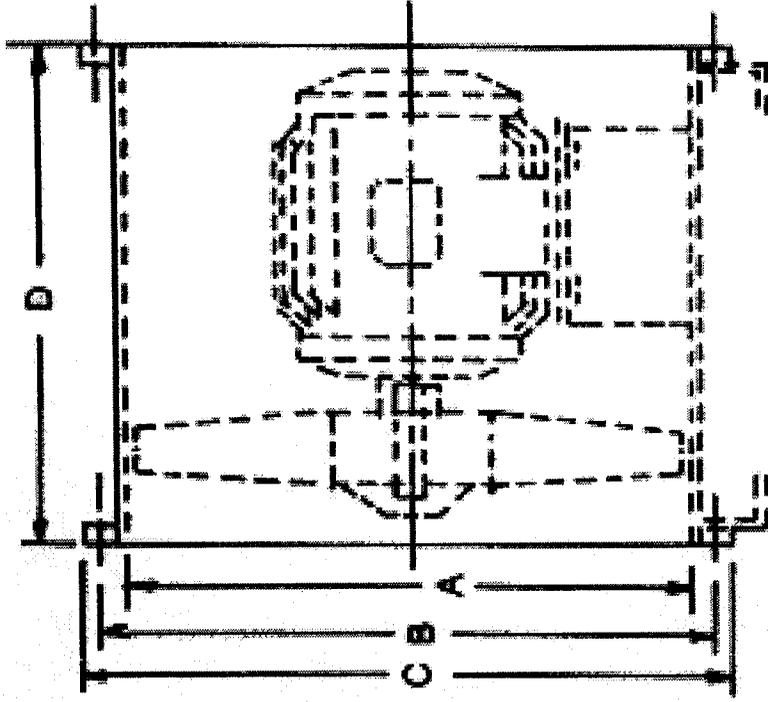
Fan Total Efficiency : 80 %

Fig. 4. Axial extraction fan

Table 9.Axial Extraction Fan Dimensions

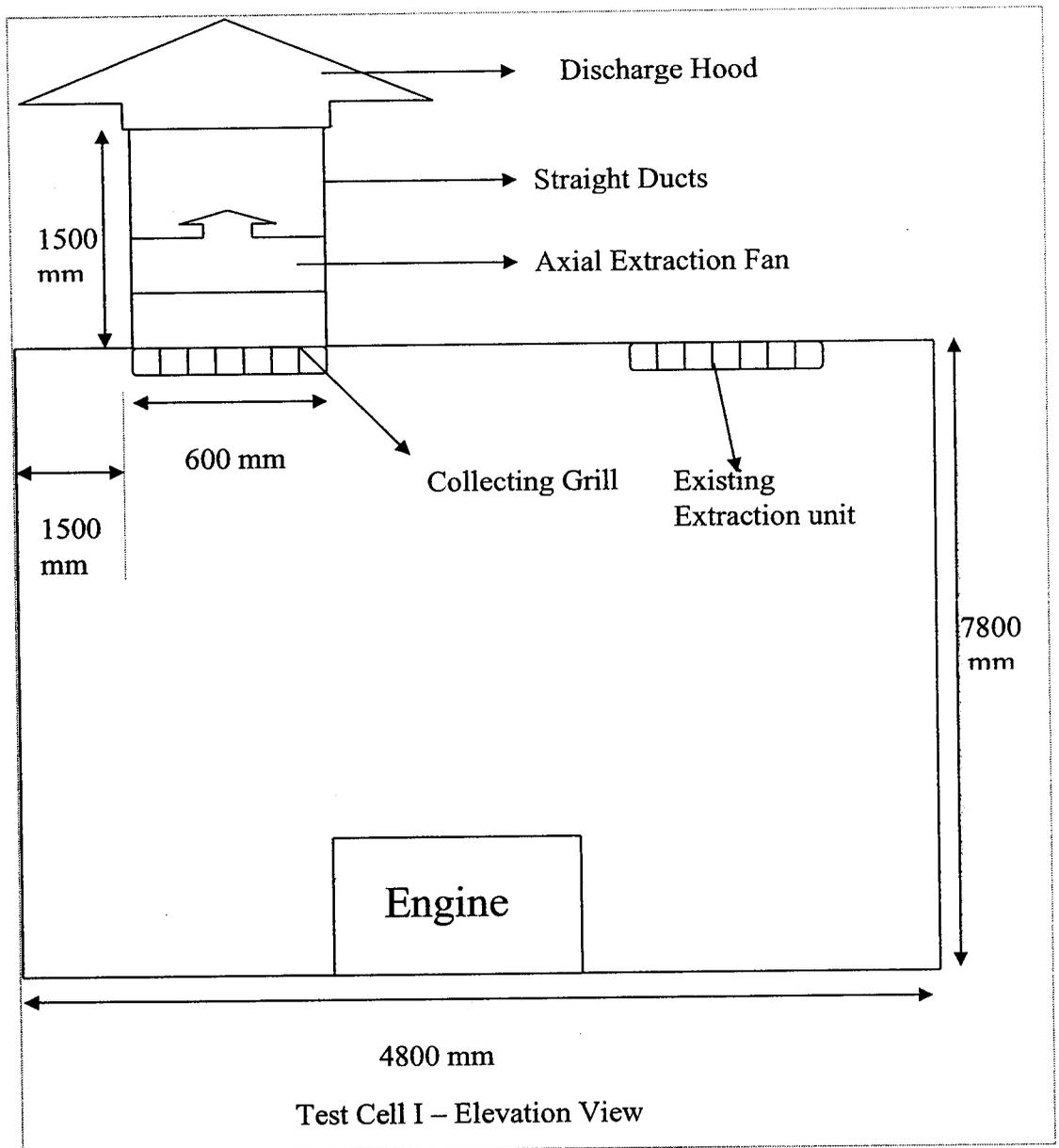| Propeller Diameter	Motor Frame size	A	B	C	D	N	P	X	Y	K	L
mm		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
380	80	385	435	471	410	245	12	380	330	10	8
380	90	385	435	471	410	245	12	380	330	10	8
482	80	485	535	571	410	335	12	480	430	12	8
482	90	485	535	571	410	335	12	480	430	12	8
482	112	485	535	571	470	335	12	480	430	12	8
482	132	485	535	571	525	335	12	480	430	12	8
610	80	614	664	700	410	355	14	600	500	12	8
610	90	614	664	700	410	355	14	600	500	12	8
610	100	614	664	700	470	355	14	600	500	12	8
610	132	614	664	700	525	355	14	600	500	12	8
610	132	614	664	700	525	355	14	600	500	12	8
760	90	765	817	853	470	450	14	750	650	14	8
760	100	765	817	853	525	450	14	750	650	14	8
760	100	765	817	853	525	450	14	750	650	14	8
760	132	765	817	853	600	450	14	750	650	14	8
914	112	920	984	1028	525	540	14	900	750	14	8
914	132	920	984	1028	600	540	14	900	750	14	8
914	132	920	984	1028	600	540	14	900	750	14	8
1220	132	1225	1293	1337	600	710	17	1200	1050	17	8

Discharge Hood

Straight Ducts

Axial Extraction Fan

1500 mm

600 mm

1500 mm

Collecting Grill

Existing Extraction unit

7800 mm

Engine

4800 mm

Test Cell I – Elevation View

Fig.5. Proposed Layout of Extraction System

5.4 Losses in the Extraction system :

Due to presence of fittings such as ducts, collecting grille etc, pressure losses occur. The next step is to calculate the pressure losses in the various elements in order to specify the pressure to be developed by the fan. For control purposes cell pressure is usually set at 50 Pa below atmospheric which gives the safest set of conditions concerning door pressurization and fume leakage. Figure 6. shows various components in diagrammatic form and indicates the loss in total pressure associated with each component made from **Galvanized Iron**. This loss is given by:

$$\Delta p_t = K_e \frac{\rho V^2}{2}$$

Where, Ke = Fitting Factor V = maximum velocity, m/s ρ = density of air , kg/m^3

Entry hood

h/d	K_e
0.5	1.3
1.0	1.1

Mitre bend

$K_e = 1.25$

Radius bend

r/a	K_e
1	0.23
2	0.14

Louvred outlet

$K_e = 0.5$

Bellmouth

$r = a/10$
$K_e = 0.15$

Diffuser

a_1/a_2	K_e
0.5	0.48
0.3	0.34

Discharge hood

h/d	K_e
0.5	1.2
1.0	1.0

Open damper

$K_e = 0.2$

Collecting hood

$K_e = 1.25$

Sudden enlargement

$K_e = 1.0$

Rectangular duct

K_e/metre

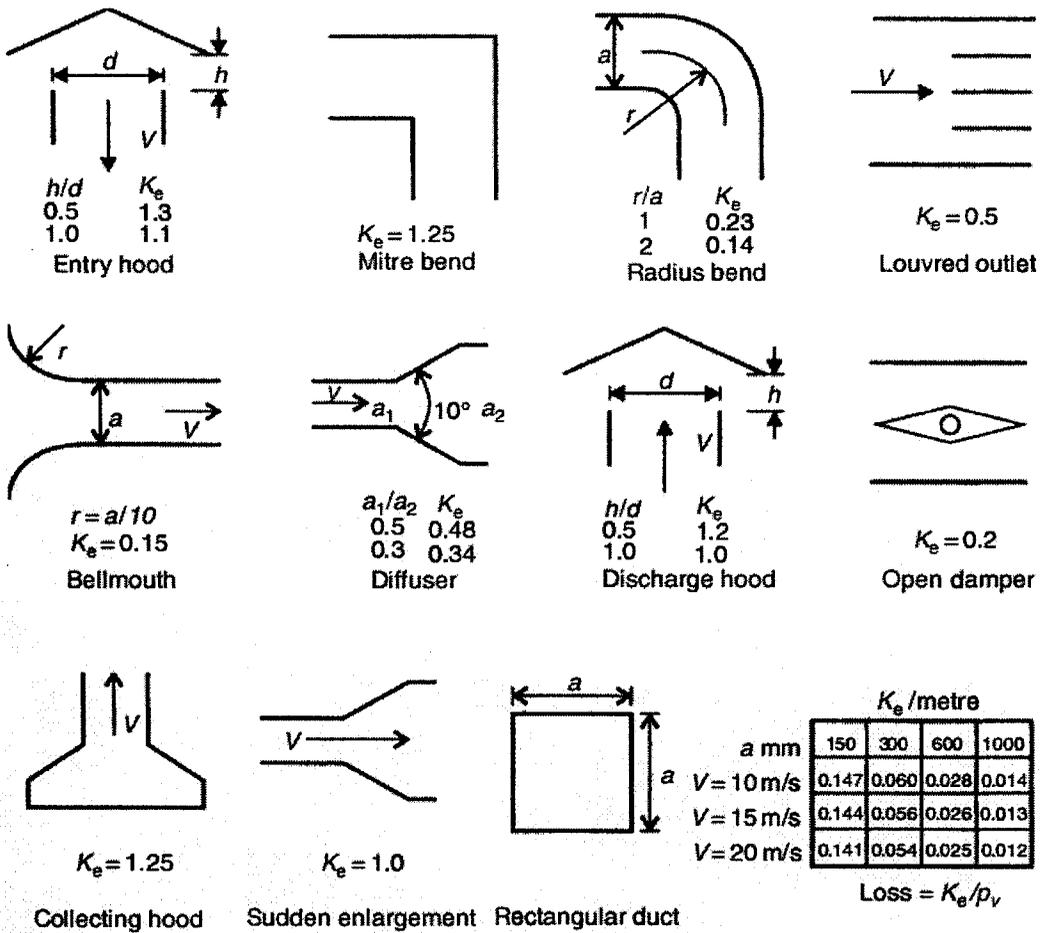| a mm	150	300	600	1000
V = 10 m/s	0.147	0.060	0.028	0.014
V = 15 m/s	0.144	0.056	0.026	0.013
V = 20 m/s	0.141	0.054	0.025	0.012

Loss = K_e/p_v

Fig.6. Pressure Losses in ventilation systems

The pressure loss per metre length of a straight duct is a fairly complex function of air velocity, duct cross-section and surface roughness. In general, the loss lies within the range 1–10 Pa/m, the larger values corresponding to smaller duct sizes. For test cells with individual ventilating systems, duct lengths are usually short and these losses are small compared with those due to bends and fittings such as fire dampers. The choice of duct velocity is a compromise depending on considerations of size of ducting, power loss and noise. If design air velocity is doubled the size of the ducting is clearly reduced, but the pressure losses are increased roughly fourfold, while the noise level is greatly increased (by about 18

dB for a doubling of velocity).Maximum duct velocities recommended are given in Table 10.

Table.11. Maximum recommended duct velocities

Volume rate of flow (m^3/s)	Maximum velocity (m/s)	Velocity pressure (Pa)
<0.1	8–9	38–55
0.1–0.5	9–11	55–73
0.5–1.5	11–15	73–135
>1.5	15–20	135–240

For the calculated volume flow rate of 3.868 m^3/s, the maximum velocity is obtained by dividing volume flow rate by area of duct i.e area of axial flow fan = 0.7 x 0.7 = .49 m^2. It gives a velocity of **7.9= 8 m/s**. The total pressure of an air flow pt is the sum of the velocity pressure and the static pressure ps :
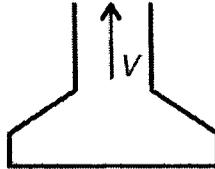
$$P_t = P_s + P_v = P_s + \frac{\rho V^2}{2}$$

The design process for a ventilating system includes the summation of the various pressure losses associated with the different components and the choice of a suitable fan to develop the total pressure required to drive the air through the system.

5.5 Calculation of Losses in the Ventilation systems :

- ## Collecting Hood :

    From Fig.6,

$$K_e = 1.25$$

Collecting hood

Now $Ke = fitting factor = 1.25$

$V = Maximum\ air\ velocity = 8\ m/s$

$\rho = Density\ of\ air = 1.046\ kg/m^3$

Pressure loss in collecting hood $= Ke\ x\ (\rho\ x\ V^2)\ /\ 2$

$= 1.25\ x\ (1.046\ x\ 64\ )/2 = 41.84\ Pa$

Therefore, **Pressure loss in collecting hood = 41.84 Pa**

- ## Straight Ducts (Square Section)

    From Fig.6,
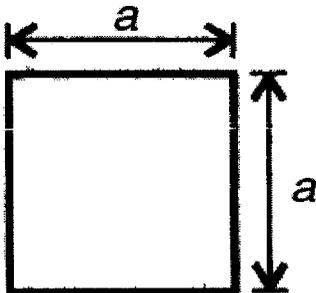
a mm	150	300	600	1000
$V = 10$ m/s	0.147	0.060	0.028	0.014
$V = 15$ m/s	0.144	0.056	0.026	0.013
$V = 20$ m/s	0.141	0.054	0.025	0.012

K_e /metre

Loss $= K_e/p_v$

To accommodate the axial fan within the duct, the side of the duct , a , must have a minimum side of **700 mm**. By interpolating values of fitting factor, Ke for a velocity , V=8m/s and side a = 700 mm , we get **Ke = 0.0245**

Now Ke = *fitting factor* =0.0245

V = *Maximum air velocity* = 8 m/s
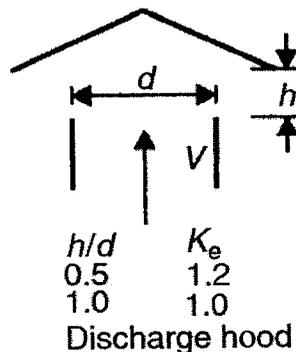
ρ = Density of air = 1.046 kg/m^3

Pressure loss in collecting hood/ m = $Ke \times (\rho \times V^2) / 2$

$= 0.0245x (1.046 \times 64)/2 = 0.820 \, Pa / m$

Therefore, **Pressure loss in duct of length 1.5 m = 0.820 x 1.5 = 1.23 Pa**

- ***Discharge Hood :***

h/d	K$_e$
0.5	1.2
1.0	1.0

Discharge hood

Now , diameter d = 1000 mm (diagonal of square duct of side 700 mm)

Height, h = 500 mm (Assumed)

h/d = 0.5 , corresponding value of fitting factor , **Ke = 1.2**

V = *Maximum air velocity* = 8 m/s

ρ = Density of air = 1.046 kg/m^3

Pressure loss in discharge hood = $Ke \times (\rho \times V^2) / 2$

$= 1.2 \times (1.046 \times 64)/2 = 40.164 Pa$

Therefore, **Pressure loss in discharge hood = 40.164 Pa**

Table.12. Losses in ventilation system

Item	Size mm	Area m²	Volume Flow rate m³/s	Velocity m/s	Velocity Pressure Pa	Fitting loss factor Ke	Pressure Drop Ke/m	Length m	Pressure loss Pa	Cumulative loss Pa
Collecting Hood	700	0.49	3.868	8	33.472	1.25			41.84	41.84
Straight Duct	700	0.49	3.868	8	33.472		0.0245	1.5	1.23	43.07
Discharge Hood	1000	0.79	3.868	8	33.472	1.2			40.164	83.234
								Total	83.234 Pa	83.234 Pa

66

5.6 Verification of Motor Power :

The losses are used to verify if the motor rating provide by the manufacturer is sufficient.

Shaft Power=(Volume flow rate x (fan total pressure))/ Fan efficiency

= (Volume flow rate x (pressure losses + cell pressure difference))/

Fan efficiency

= (3.868 x (83.234 + 50)) / 0.80

= 644 Watts.

Manufacturer's motor rating is 0.75 kW = 750 Watts. Hence the selected model satisfies the requisites for test cell ventilation.

CHAPTER 6. DESIGN OF INDUCTION AIR DUCT

6.1 Proposed Design of Induction air Duct :

In order to isolate the induction air from the ambient air conditions, it is proposed to set up an enclosed line from the engine to atmospheric air. The passage consists of a flexible circular duct from the compressor side of the turbo charger to a circular iron duct anchored to the walls of the test cell. The iron ducts lead through the air inlet passages on either side of the test cell door, opening up to the atmosphere above the cell ceiling. The air filters are fitted at the end of the duct above the test cell roof.   The layout rendered in Autocad is shown in Fig.7 & Fig8.

6.2 Duct Losses Calculation (Theory) :

As air flows through a duct its total pressure drops in the direction of flow. The pressure drop is due to:

- Fluid friction
- Momentum change due to change of direction and/or velocity

The pressure drop due to friction is known as frictional pressure drop or friction loss, Δp_f. The pressure drop due to momentum change is known as momentum pressure drop or dynamic loss, Δp_d. Thus the total pressure drop Δp_t is given by:

$$\Delta p_t = \Delta p_f + \Delta p_d$$

6.2(a) Frictional pressure drop in ducts:

The Darcy-Weisbach equation is one of the most commonly used equations for estimating frictional pressure drops in internal flows. This equation is given by:

$$\Delta p_f = f \frac{L}{D} \left(\frac{\rho V^2}{2g} \right)$$

where f is the dimensionless friction factor, L is the length of the duct and D is the diameter in case of a circular duct and hydraulic diameter in case of a non-circular duct. The friction factor is a function of Reynolds number,

$$Re_D = \left(\frac{\rho VD}{\mu} \right)$$

and the relative surface roughness of the pipe or duct surface in contact with the fluid. For turbulent flow, the friction factor can be evaluated using the empirical correlation suggested by Colebrook and White is used, the correlation is given by:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\frac{k_s}{3.7D} + \frac{2.51}{(Re_D)\sqrt{f}} \right]$$

where k_s is the average surface roughness of inner duct expressed in same units as the diameter D. Evaluation of 'f' from the above equation requires iteration since f occurs on both the sides of it. In general in air ducts, the fluid flow is turbulent. It is seen from the above equation that when the flow is turbulent, the friction factor is a function of Reynolds number, hydraulic diameter and inner surface roughness of the duct material. Table.13 shows absolute roughness values of some of the materials commonly used in ducts:

Table.13 Absolute roughness values of commonly used Duct materials

| Surface	Roughness – k_s	
	10^{-3} (m)	(feet)
Copper, Lead, Brass, Aluminum (new)	0.001 - 0.002	3.33 - 6.7 10^{-6}
PVC and Plastic Pipes	0.0015 - 0.007	0.5 - 2.33 10^{-5}
Epoxy, Vinyl Ester and Isophthalic pipe	0.005	1.7 10^{-5}
Stainless steel	0.015	5 10^{-5}
Steel commercial pipe	0.045 - 0.09	1.5 - 3 10^{-4}
Stretched steel	0.015	5 10^{-5}
Weld steel	0.045	1.5 10^{-4}
Galvanized steel	0.15	5 10^{-4}
Rusted steel (corrosion)	0.15 - 4	5 - 133 10^{-4}
New cast iron	0.25 - 0.8	8 - 27 10^{-4}
Worn cast iron	0.8 - 1.5	2.7 - 5 10^{-3}
Rusty cast iron	1.5 - 2.5	5 - 8.3 10^{-3}
Sheet or asphalted cast iron	0.01 - 0.015	3.33 - 5 10^{-5}
Smoothed cement	0.3	1 10^{-3}
Ordinary concrete	0.3 - 1	1 - 3.33 10^{-3}
Coarse concrete	0.3 - 5	1 - 16.7 10^{-3}
Well planed wood	0.18 - 0.9	6 - 30 10^{-4}
Ordinary wood	5	16.7 10^{-3}

6.2(b) Dynamic pressure drop in ducts:

Dynamic pressure loss takes place whenever there is a change in either the velocity or direction of airflow due to the use of a variety of bends and fittings in air conditioning ducts. Some of the commonly used fittings are: enlargements, contractions, elbows, branches, dampers etc. Since in general these fittings and bends are rather short in length (< 1 m), the major pressure drop as air flows through these fittings is not because of viscous drag (friction) but due to momentum change. Pressure drop in bends and fittings could be considerable, and hence should be evaluated properly. However, exact analytical evaluation of dynamic pressure drop through actual bends and fittings is quite complex. Hence for almost all the cases, the dynamic losses are determined from experimental data. In turbulent flows, the dynamic loss is proportional to square of velocity. Hence these are expressed as:

$$\Delta p_t = K_e \frac{\rho V^2}{2}$$

Where, Ke is the Dynamic loss coefficient or Fitting Factor, which is normally obtained from experiments. Fig.6 displays the coefficient values for some of the commonly used duct components.

6.2(c) Losses in flexible ducts:

 The proposed design utilizes heavy duty flexible plastic hosing to connect the compressor side of the turbochargers to the iron ducts. This presents an increased pressure drop due to the 'Bellow' structure of the hose. The flow inside the induction passage is considered as a turbulent flow. At lower Reynolds numbers (only turbulent flow), the friction factors for straight flexible hoses were found to be approximately two to three times larger than for commercial cast iron pipe of average roughness; the higher friction values were found to hold true for the smaller pipes. At the larger Reynolds numbers, the friction factors were found to be 3.5 to 7 times higher than for non-flexible pipes. Curved hoses had a consistently higher friction factor than straight hoses. With few exceptions, curved hoses showed an increase in friction factor with an increase in angle of bend. At 180 ° bends and for the same diameter, the friction factors were found to be 1.5 to 2 times higher than at 0 ° angle of bend. The radius of bend has little influence. ("Friction Factors of Straight and Curved Flexible Metal Hoses as a Function of Reynolds Number." By Goodloe, J. H. and H. Paul)
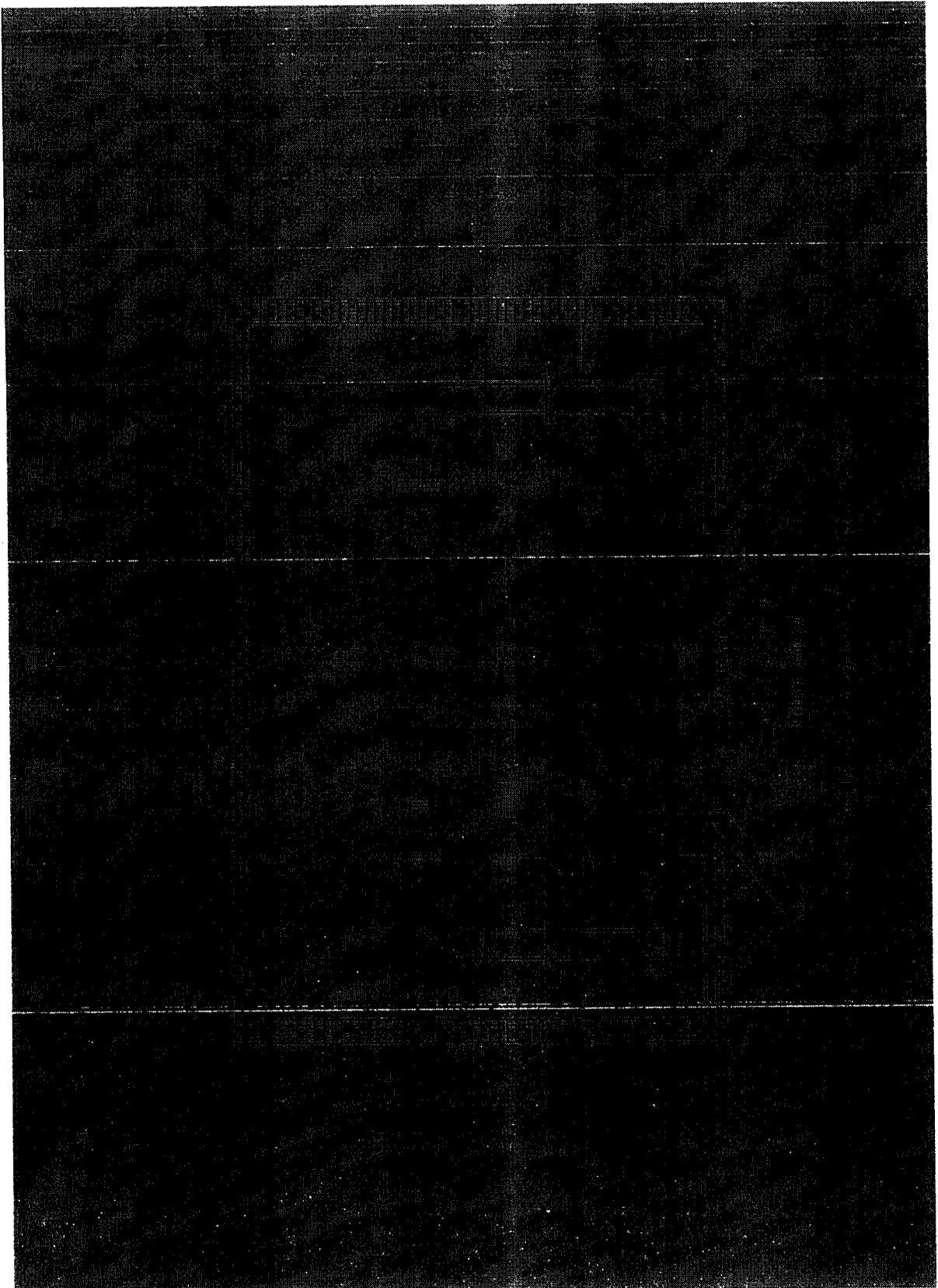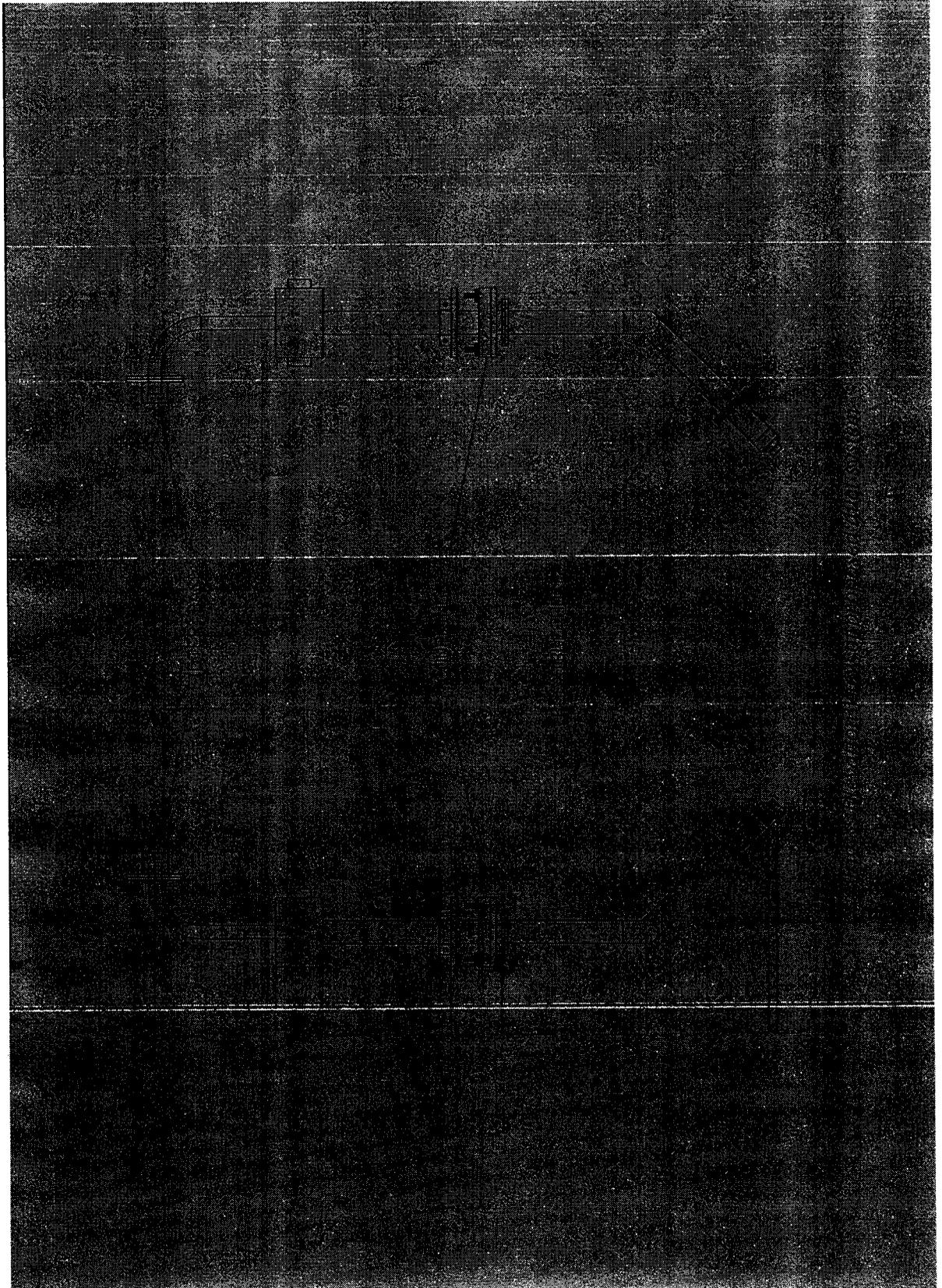
6.3 Evaluation of Pressure drop in proposed ducting system :

Frictional Losses :

For ease of calculation, the pressure loss is calculated separately for the iron duct and flexible hosing. The calculations are based on the maximum induction air requirements i.e Volume flow rate = 45 m^3/min = 0.75 m^3/s . There are two ducts which are connected to repective turbochargers.

For smooth iron pipe :

1. Reynolds No,
$$Re_D = \left(\frac{\rho VD}{\mu} \right)$$

ρ = Density of fluid (air) = 1.046 kg/m^3

μ = Dynamic viscosity of air (@ 25 Deg C) = 5.268 x 10^{-7} Ns/m^2

D = Diameter of duct, D = 250 mm =0.25 m

V= Velocity of flow =(Volume of Induction air / no of ducts)

/Duct Area $\qquad = (0.75 / 2) /(? \times D^2)/4)$

$\qquad = 0.375 / 0.049$

$\qquad = 7.65 = 8$ m/s

Re = (1.046 x 8 x 0.25) / (5.268 x 10^{-7}) = **3.97 x 10^6**

As Re > 4000, it's a **Turbulent flow.**

Friction Factor for Turbulent flow is given by,

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\frac{k_s}{3.7D} + \frac{2.51}{(Re_D)\sqrt{f}}\right]$$

Where, f = friction factor

Ks = Roughness factor (Cast Iron) = 2×10^{-3} m

D = Diameter of pipe = 0.25 m

Re = Reynolds no = 3.97×10^{6}

Calculating , we get, Fiction factor f = **0.0352151**

Frictional pressure drop is given by

$$\Delta p_f = f\frac{L}{D}\left(\frac{\rho V^2}{2}\right)$$

Where , f = 0.0352151

 D = Diameter of duct = 0.25 m

 V = velocity = 8 m/s

 ρ = Density of air =1.046 kg/m^3

L = Lengt of duct (obtained from the diagram) = 7 m

Pressure drop = (0.0352151/ 2) x (7 / 0.25) x (1.046 x 8^2)

= 33 Pa

Therefore, frictional pressure drop in smooth pipe = 33 Pa

For flexible pipe :

1. Friction Factor for flexible piping is given by,

= Flexibility factor x Friction factor of smooth pipe

= 7 x 0.0352151

= 0.105 x 10^{-4} m

Calculating, we get Friction factor f = 0.246

Frictional pressure drop is given by

$$\Delta p_f = f \frac{L}{D} \left(\frac{\rho V^2}{2} \right)$$

Where, f = **0.246**

D = Diameter of duct = 0.25 m

V = velocity = 8 m/s

ρ = Density of air = 1.046 kg/m³
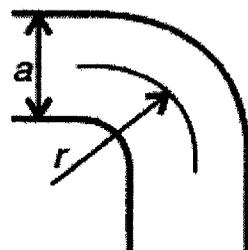
L = Maximum Length of duct (obtained from diagram) = 3.5 m

Pressure drop = (0.246/ 2) x (3.5 / 0.25) x (1.046 x 8²)

$$= 115.277 = 116 \text{ Pa}$$

Therefore, frictional pressure drop in flexible pipe = 116 Pa

Dynamic Losses :

For smooth pipe

1.**Radius bend :** From Fig .6 ,

r/a	K_e
1	0.23
2	0.14

Radius bend

From the given drawing,

Radius of bend, r = 300 mm

Diameter of pipe, a = 250 mm

Therefore , r/a = 1.2

Interpolating dynamic coefficient factor for r/a =1.2, we get **Ke = 0.212**

Now   Ke = fitting factor =0.212

V = Maximum air velocity = 8 m/s

ρ = Density of air = 1.046 kg/m^3

Pressure loss in radius bend = Ke x (? x V^2) / 2

= 0.212 x (1.046 x 64)/2 = 7.09 Pa

There are two such elbows present in the proposal,so the pressure drop is doubled.Therefore,

Pressure loss in radius bend = <u>14.18 Pa</u>

2. Sudden Enlargement (Reservoir): From Fig 6.
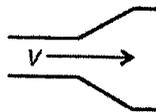
$K_9 = 1.0$

Sudden enlargement

Now   Ke = fitting factor = 1

ρ V = Maximum air velocity – min velocity = 8 – (8x a1/a2)

a1 = area before enlargement = 0.049 m^2

a2 =area after enlargemen=(lengthxbreadth)=(0.3x0.35)=.105 m^2

ΔV = 8 – (8 x (0.049 / 0.105)) = 4.266 m/s

ρ = Density of air = 1.046 kg/m^3

Pressure loss due to sudden enlargement = Ke x (? x ? V^2) / 2

= 1 x (1.046 x 4.266^2)/2 = 33.47 = 9.34 Pa

Therefore, Pressure loss due to sudden enlargement = <u>9.34 Pa</u>

3.Sudden Contraction (Reservoir)

It is a mirror image of the sudden enlargement but Ke is assumed as 1.25Therefore ,

Pressure loss due to sudden contraction =1.25 x 9.34 = 11.6 pa

For flexible pipe :

The flexible piping consists of a single radius bend at the point where it meets the turbocharger. Hence we assume the radius of curvature to be the same and multiply the losses in the radius bend of smooth pipe by a flexibility factor of 7. Therefore,

Pressure loss in radius bend (flexible piping)= 7 x 14.18= 99.26=**100 Pa**

Table.14 Pressure Loss in Induction system

S.no	Item	Size mm	Area m²	Volume Flow rate m³/s	Length m	Velocity m/s	Pressure loss Pa	Cumulative loss Pa
	Frictional Losses							
1.	Smooth Pipe	250 dia	0.49	0.375	7	8	33	33
2.	Flexible Pipe	250 dia	0.49	0.375	3.5	8	116	149
	Dynamic Losses							
3.	Radius Bend (r = 300mm)		0.49	0.375		8	14.18	163.18
4.	Sudden Enlargement	350 x 300	0.105	0.375		8 ~ 3.4	9.34	172.52
5.	Sudden Contraction	250 dia	0.049	0.375		3.4 ~ 8	11.6	184.12
6.	Flexible pipe bend (r= 300mm)	250 dia	0.049	0.375		8	100	284.12
						Total Pressure drop		284.12 Pa

6.4 Verification of Design :

The Total Pressure drop is given by the sum of losses in the ducts and the pressure drop across the air filter. The restriction offered by air filter fitted n the standard engine packages of 3412 (725 KVA), 3412 (773 D) and C-18 (600 KVA) is **3.7 kPa**. (Engine Technical Specifications).

The air filters fitted on the engines during testing are considerably larger and the maximum pressure drop measured across the filters was measured as **140 mm of water or 1.372 kPa**.

Therefore, **Total Inlet Air Restriction (Design)** =

Pressure drop across air filter + Pressure drop in ducts

= 1.372 + 0.284 = **1.656 kPa**

From the Test Specification for the three engines under consideration , the **maximum inlet air restriction specified is 4 kPa.**

Since the design value **(1.656 kPa)** is within the test specification **(4.0kPa),** the design satisfies the requisites of the project. Thus the design has been verified to fit to the constraints for effective testing of the above mentioned engines at rated power without deration caused due to increased cell temperatures.

CHAPTER 7. COST ANALYSIS

7.1 Cost Analysis for modified exhaust stack of C-18 Genset engine :

Table 15. Cost Analysis for modified exhaust stack of C-18 Genset engine

S.no	Item	Dimensions mm	Length /no.of units	Cost/ unit (Rs)	Taxes (4 % VAT) (Rs)	Total (Rs)	Cumulative Cost Rs
1.	Flexible High temperature Metal Hosing	250	1 m	1,250	50	1,300	1,300
2.	Jubilee Clips	250	2 nos.	150	6	312	1,612
3.	Labor Charges	-	-	-	-	500	2,112
					Total Cost		Rs. 2,112/-

7.2 Cost Analysis for engine Induction air ducts :

Table 16. Cost Analysis for engine induction air ducts

S.no	Item	Dimensions mm	Length /no.of units	Cost/ unit (Rs)	Taxes (4 % VAT) (Rs)	Total (Rs)	Cumulative Cost Rs
1.	Cast iron Pipe(smooth duct)	Dia – 300 Thickness - 17.84	14 m	2,000	80	29,120	29,120
2.	Flexible PVC Duct hose	250	3.5	966	39	3,015	32,135
3.	Jubilee Clips	250	6	150	6	936	33,071
4.	U – clamps	250	10	90	3.5	935	34,006
5.	Labor Charges (Fabrication)	-	-	-	-	2000	36,006
6.	Labor Charges (Installation)	-	-	-	-	1000	37,006
					Total Cost		Rs. 37,006

7.3 Cost Analysis for Ventilation Components:

Table 17. Cost Analysis for Ventilation Components

S.no	Item	Dimensions mm	Length /no of units	Cost/ unit (Rs)	Taxes (4% VAT) (Rs)	Total (Rs)	Cumulative Cost Rs
1.	Galvanized iron Duct (including losses)	250 x 250	2.5 m 7 m^2	800 / m^2	32	5,824	5,824
2.	Labor Charges (Fabrication & installation)	-	-	-	-	2500	8,324
3.	Axial Extraction Fan (8500 CFM)	610 mm	1 nos	-	-	22,500	30, 824
					Total Cost		Rs.30,824

Thus , the estimated cost of implementation of the proposed design is the sum of the various costs

Total Cost = Cost of modified exhaust stack for C- 18 Genset engine +Cost of ventilation
components + Cost of engine air induction ducts
= 2,113 +37,006 +30,824 = Rs.69,943 = Rs.70,000

Therefore, Total estimated cost = Rs.70,000

M/s Cater Piller India
(Pvt.) Ltd.
Coimbatore.

Ref. No. KTC / CBE / 217/08-09

Date : 13-1-09.

Dear Sirs,

While thanking you very much for your enquiry No. Verbal........ dated 13/1/09.........
we are pleased to quote our lowest as under. We hope you will find our rates most
competitive and favour us with your valued orders per return.

Item	Qty.	DESCRIPTION	@ Rs.	Unit
1.		PVC Dea't Hose	966.00	Pr mtr
		250 mm ("10")		
		d.F 8% 10/.		
		(+) VAT A/. Extra		

The above is/are as godown / F.O.R. @ Coimbatore.

Terms : As above.

Delivery : Ready Stock Subject to Prior Sales.

Payment : Cash against delivery.

Validity : The above offer is valid for 15 days from the date of opening.

For Kamlesh Trading Corporation

Manager

*Fig.7. Quote Received for flexible plastic hosing obtained from
M/s Kamlesh trading corporation, Coimbatore*

8. Conclusion :

The primary goals of the project i.e.

- Identification of factors causing deration of engines
- Quantification of the factors through data collection
- Analysis of data
- Formulation of a proposal to rectify these factors

were achieved. The submitted design was selected with stress on simplicity and cost effectiveness. It also included extensive discussions with the test technicians to identify possible problems in implementation of the proposal. A cost analysis based on local retail prices was also done to ensure cost-effectiveness of the proposal.

Through the course of the project , the team was able to obtain valuable experience and knowledge through observation , guidance and interactions and wish to thank the management of **Caterpillar India Pvt. Ltd (PSD)** for the opportunity provided.

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