APPENDIX A - TECHNICAL SPECIFICATIONS

1 Turbine and Site Conditions

Type:	Crossflow/Mitchell Banki
Capacity:	2.5 kW
Max Flow:	250 L/s
Gross Head:	2.86 m
Net Head:	1.68 m
Length:	810 mm
Diameter:	316 mm
Material:	Mild Steel (electroplated)
Number of Blades:	20
Blade Diameter:	4”
Blade thickness:	4mm
Plate thickness:	¼” (6mm)
Shaft Diameter:	1” (25.4mm)

2 Generator (Induction Motor)

Manufacturer:	ABB
Website:	www.abb.com
Size:	4 HP
Number of Poles:	4
Number of Phases:	3
Insulation:	Class F
Weight:	45 kg
Frame:	112

Manual (English and Spanish):
http://www05.abb.com/global/scot/scot259.nsf/veritydisplay/1dd3ba07ab27290bc1257575002413a7/$File/LVStdMotorsManual_ML_01_2009.pdf

3 Gearbox

Manufacturer:	Fenner
Website:	www.fptgroup.com
Size:	802
Ratio:	10.887:1
Rating:	311 Nm

4 Coupling 1 (between turbine and gearbox)

Manufacturer:	LoveJoy
Website:	www.lovejoy-inc.com
Size:	L225
Type:	Jaw
Rubber:	SOX
Rating:	264 Nm

More Technical Information (English): http://www.lovejoy-inc.com/uploadedFiles/Catalogs/jw.pdf

Installation Instructions (English): http://www.lovejoy-inc.com/uploadedFiles/Technical_Resources/JawInstruction.pdf

5 Coupling 2 (between gearbox and generator)

Manufacturer:	LoveJoy
Website:	www.lovejoy-inc.com
Size:	L100
Type:	Jaw
Rubber:	SOX
Rating:	47.1 Nm

See contact information, technical information and installation instructions above.

6 Turbine Bearings

Manufacturer:	SKF
Website:	www.skf.com
Size:	SY1 TF

More technical information on bearing:
http://www.skf.com/skf/productcatalogue/Forwarder?action=PPP&lang=en&imperial=true&windowName=null&perfid=211171&prodid=2111715100

7 Transformer

Manufacturer:	Cutler Hammer
Type:	Single Phase
Capacity:	5 KVA
Voltage:	120 to 240V AC
Weight:	49 kg
Impedance:	2.5

8 PVC Flanges

Manufacturer:	Spears
Outer Diameter:	13.5”
Number of Bolts:	8
Bolt Size:	¾”

More technical information on PVC flanges (see page 7):
http://www.spearsmfg.com/prod_dimensions_spec/FL-4-0109_0109_web.pdf

Appendix B – References

Author/Title/Publisher	Type	Rating	Comments
Azim, N.M. & Desai, V.R., An Experimental Study of the Effect of Some Design Parameters on Crossflow Turbine Efficiency, Clemson University, Sth Carolina (no date)	Engineering Report (52 pages scanned)	2	Experimental study that looked at effect of parameters on efficiency. 27 turbines and 3 nozzles were tested. Includes literature review. Not much theory is given and parameters are not explained properly. The only real conclusion from the paper is that more blades improves efficiency (25 is better than 15).
Banki-Crossflow Systems Design Guide & Walsh River Micro-Hydro Turbine Construction Guide	Design paper (7 pg), construction manual (9 pg) and excel sheet	3	Docs from Planetary Power in Nth Qld, Australia. Design doc doesn't include any turbine theory and is more of a guide to the excel sheet. It does not explain where the formulas in the sheet come from and if they are based on experimental or theoretical data. Construction document is not very thorough and no dimensioned drawings. There are a few good tips on construction though.
Barglazan, M., About Design Optimisation of Cross-Flow Hidraulic Turbines, University of Timisoara, Romania (2005)	Paper (5 pages)	1	Not a very useful paper. Lots of maths that is not very well explained in bad English. Software was developed to find optimum turbine parameters but results not explained fully.
Breslin, W.R., Small Mitchell (Banki) Turbine: A Construction Manual, VITA (1980)	Manual (65 pages)	4	Fairly basic theory. 30cm diam runner. Claims efficiency is 80% or greater. Has a fair amount of detail on fabricating from steel plate.
Callaert, A., The Banki Water Turbine Erratum (no date)	Summary (1 page)	4	1 page summary of formulas from "Bulletin 25" that are corrected
Durali, M., Design of Small Water Turbines for Farms and Small Communities, Massachusetts Institute of Technology (1974)	Master of Science Paper (150 pages scanned)	2	Looked at 4 different turbine designs for 5kW and 10m of head. Includes design review of Banki turbine and lots of theoretical mathematics. Final design had 24 blades riveted to sides but doesn't look like it was ever built. Interesting information on nozzle flow control.
Durgin, W.W., Fay, W.K., Some Fluid Flow Characteristics of a Cross-Flow Type Hydraulic Turbine, Worcester Polytechic Institute, Massachusetts (no date)	Paper (17 pages)	3	Testing of a crossflow turbine found that not much power was derived from second stage flow through turbine. Max efficieny attained was 61%
Harvey, A., Micro-Hydro Design Manual – A Guide to Small-Scale Water Power Schemes, ITDG Publishing (1993)	Book	5	Good overall information on micro-hydro system design (civil, electrical and mechanical). Explanations of different turbine types (including Crossflow Turbines) with mathematical formulas.
Marchegiani, A.R., Turbina de Flujo Transversal o Mitchell-Banki Universidad Nacional del Comahue,	Paper (25 pages)	5	A design doc for a Crossflow Turbine written in Spanish. The document is fairly comprehensive and contains good design

Argentina (no date)			information on nozzle shape.
Meier, U., Design of Cross-Flow Turbine, Swiss Centre for Appropriate Technology (no date)	Design Drawings (113 pages, badly scanned)	1	Only drawings and no text
Mockmore, C.A. & Merryfield, F., The Banki Water Turbine, Engineering Experiment Station, Oregon State College, 1949	Bulletin (28 pages scanned)	5	This document is the basis for many turbine designs and contains a translation (from German) of Banki's theory. The second half of the document then describes an experimental test performed.
Shigley, J.E & Mischke, C.R., Mechanical Engineering Design, McGraw-Hill (1989)	Book	4	Good engineering design book used for stress calculations
Smith, N., Motors as Generators for Micro-hydro Power, Practical Action Publishing (1994)	Book	4	A guide to the use of induction motors for electricity generation
Thake, J., The Micro-Hydro Pelton Turbine Manual: Design, Manufacture And Installation For Small-Scale Hydropower, Practical Action Publishing (2001)	Book	4	Manual for the design of Pelton Turbines. Information on sizing tailrace channels for micro-hydro systems.
White, F.M., Fluid Mechanics, McGraw-Hill (1979)	Book	4	Useful fluid mechanics text used for calculating head losses
www.lightmypump.com/micro-hydro-banki.htm	Website	5	Has good reference documents attached (discussed in this table). Page isn't complete but discusses overall theory and turbine dimensions.
www.ossberger.de/cms/en/hydro/the-ossberger-turbine/	Website	3	The ossberger is an efficient commercially made turbine designed and made in Germany. No design information given.
www.entec.ch	Website	2	Entec produce the T15 Turbine, a commercially made turbine and the latest in the range of SKAT turbines. No design information given.

APPENDIX C – CONTACT DETAILS

1 Steel Suppliers

Name:	Casa DR
Description:	Large steel supplier who provided angle iron and sheet metal for project
Address:	13 Avenida 4-17 Zona 3, Xela
Phone:	7720 5252

Name:	Candelaria, SA
Description:	Large steel supplier that had the best price for 4” tubing used for turbine
Address:	19 Avenida, on hill just before Tecun Uman roundabout
Phone:	

2 Machinists

Name:	Tornos Gutierrez
Description:	The hubs and turbine discs were fabricated by Adani at Tornos Gutierrez
Address:	Diagonal 2 0-88A Zona 5, Xela
Phone:	7761 4047

3 Metal Cutting and Bending

Name:	Taller de Estructuras Metalicas, San Mateo
Description:	This workshop has a simple plasma cutter that was used for cutting the turbine discs and parts for the nozzle. Remigio is the boss.
Address:	Diagonal 2, 1-71 Zona 3 Carretara Interamericana, San Mateo
Phone:	7756 4712, 7762 5699

Name:	Construcciones Industriales de Occidente (Don Claus)
Description:	This workshop has bending and cutting machines. They were used to cut and bend the nozzle parts.
Address:	2a. Calle 5-15 Zona 9, Xela (Bottom of Cuesta Blanca)
Phone:	

4 Galvanising Workshop

Name:	Grupo ITM
Description:	Largest galvanising facility in Central America. Contact was Patty Morales. www.grupoitm.net
Address:	2 Av. 5-98 Zona 6, Lotification Los Alamos, Km 18 Carratera a Villa Canales
Phone:	6628 0000

5 Generator Supplier

Name:	Motores Electricos de Guatemala S.A
Description:	Motor Supplier
Address:	Calzada Aguilar Batres 45-99, zona 12, Guatemala City
Phone:	

6 Gearbox Supplier

Name:	ERIKS International
Description:	Contact was Cliff Ward
Address:	Unit 4D Amsterdam Road, Sutton Fields Industrial Estate, Hull HU7 0XF
Phone:	

7 Bearings and Couplings Supplier

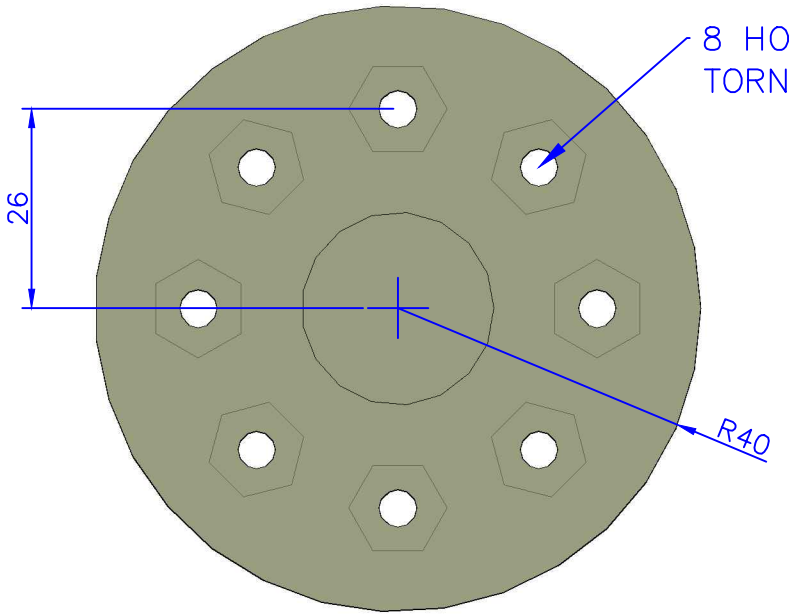
Name:	Benjamin Caceres Rojas
Description:	
Address:	4 Calle, 13-34, Zona 3, Quetzaltenango, Guatemala
Phone:	+502 7763 5557

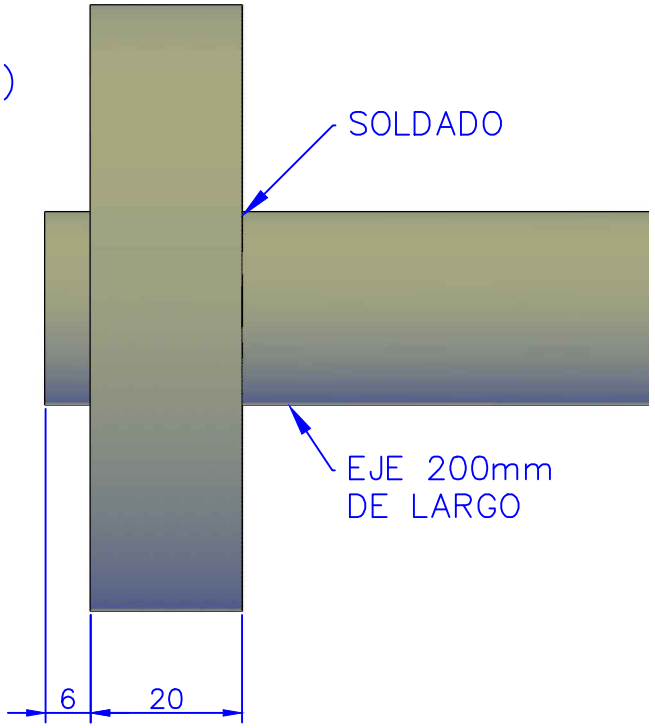
8 Electrical Controller Supplier

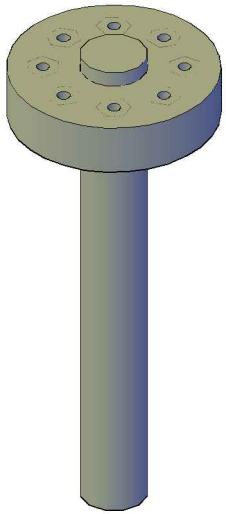
Name:	Soluciones Prácticas - ITDG
Description:	Practical Action (ITDG). Contact is Celso Dávila Vásquez
Address:	Av. Jorge Chávez 275, Miraflores, Lima, Perú
Phone:	(511) 4447055, 4475127, 2429714, (f) 4466621

9 Transformer Supplier

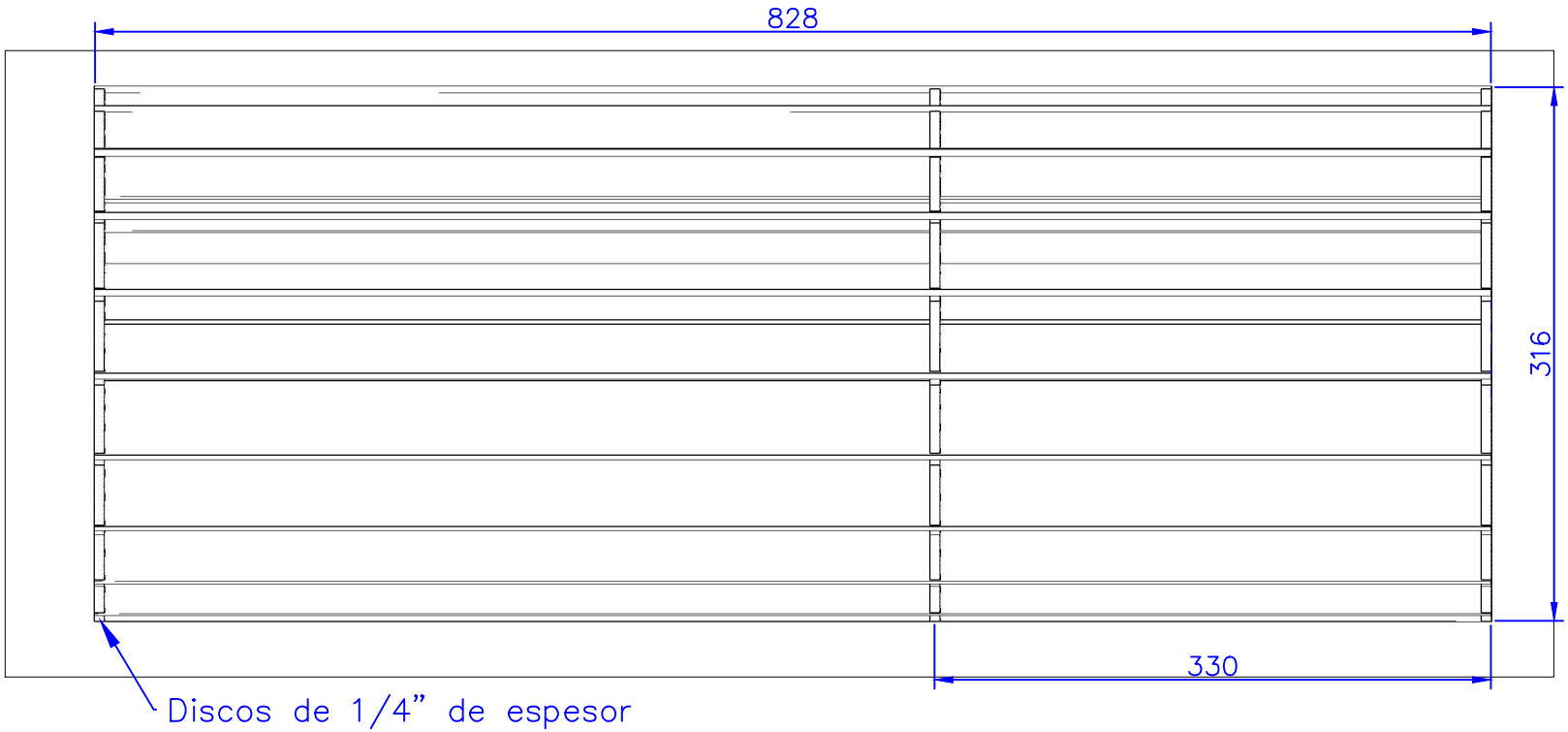
Name:	Ceica
Description:	Large electrical supplier in Xela
Address:	18 avenida 0-37 zona 3 Quetzaltenango, Quetzaltenango
Phone:	7765 2841



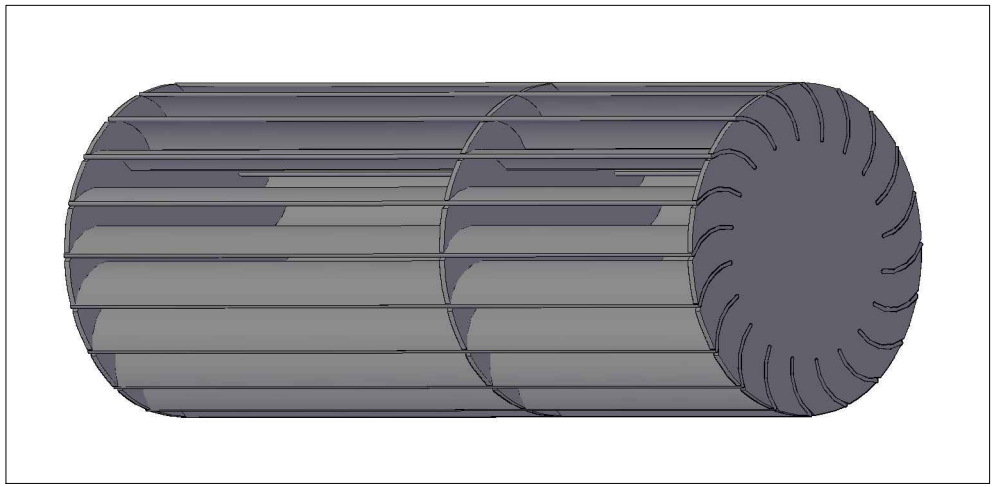




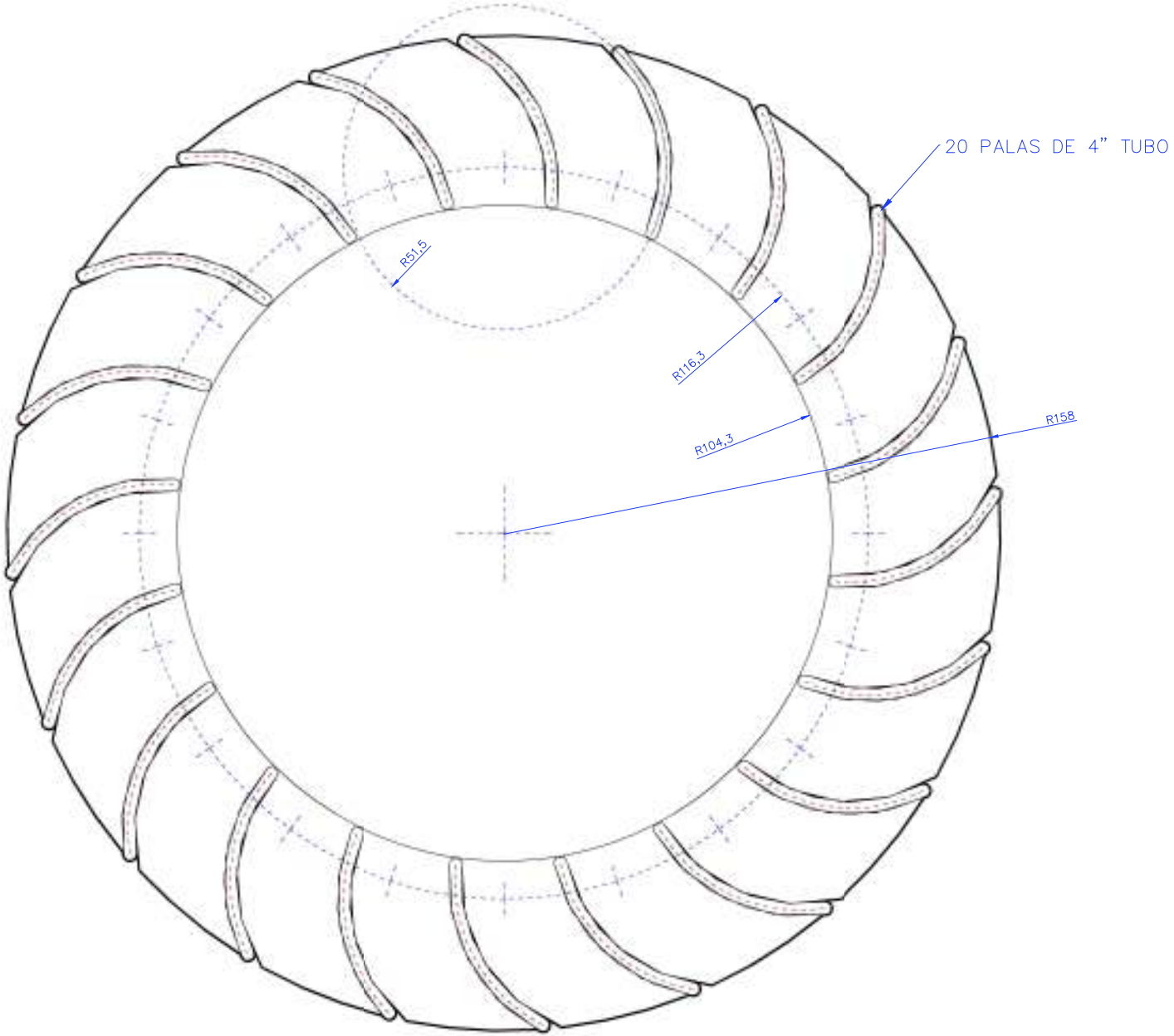
AIDG	PROJECT: MITCHELL–BANKI		
	DWN NAME: MAZA DE LA TURBINA		
DATE: 8/11/09	DRAWN BY: W. STONE	CHECKED BY:	APPROVED BY:
DWN NO: 0002	SHEET: 1 OF 1	SCALE: 1:1	SIZE: LETTER



Notas
1. Dimensiones en mm
2. Hay 20 Palas de 4" Tubo



AIDG	PROJECT: MITCHELL–BANKI		
	DWN NAME: TURBINE DIMENSIONS		
DATE: 12 OCT 09	DRAWN BY: W. STONE	CHECKED BY: S. CROWE	APPROVED BY:
DWN NO: 0001	SHEET: 1 OF 1	SCALE: 1:4.3	SIZE: LETTER


20 PALAS DE 4" TUBO
R51,5
R116,3
R104,3
R158