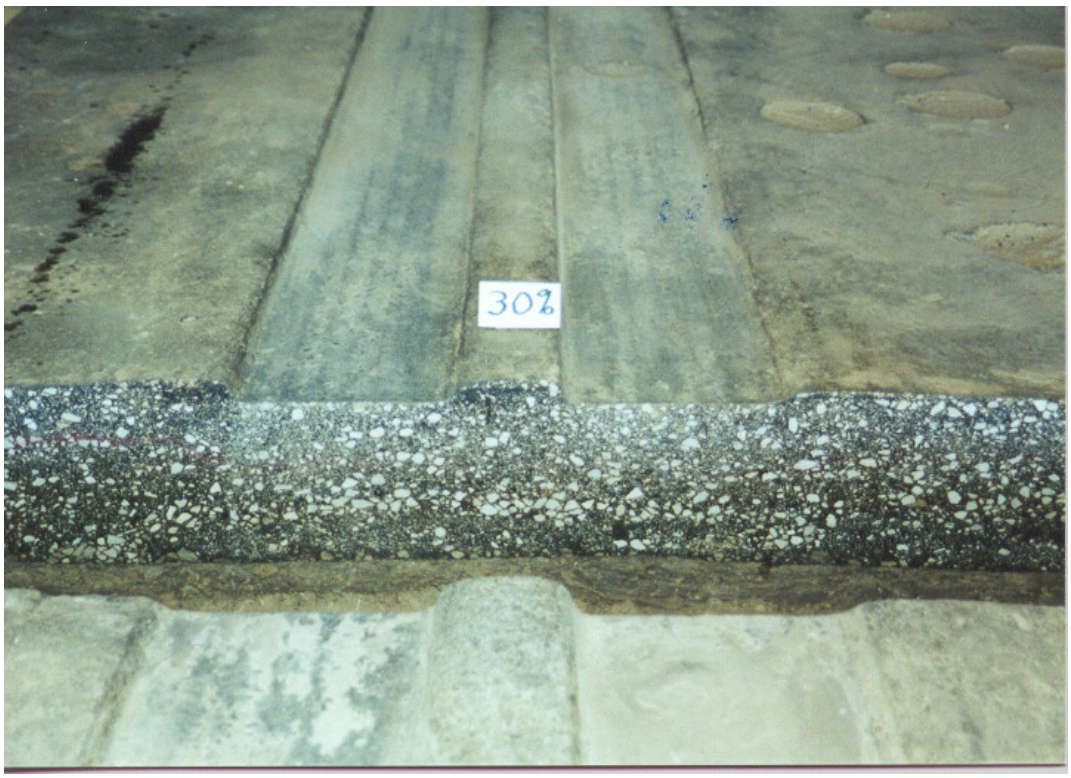


Figure 5.18 Side Wall of Cut Trench in SM-2A Test Section with 30% Sand

5.7 Summary and Conclusions

The experiment met the estimated maximum number of passes for each of the control sections and test sections, which is 80,000 repetitions. A fixed wheel pass (zero lateral wander) was followed and two-pass cycles (two-way traffic) were applied throughout the tests. Loading consisted of rolling wheel passes of a dual tandem axle of 150 kN (34 kips). Tire pressure was 620 kPa (90 psi). In general, load cycles were applied when the surface temperature of the pavement was around 50°C (122°F) while mid-depth temperature was maintained around 37.8 ± 2.2°C (100 ± 4°F). Consequently, the temperature gradient between the surface and mid-depth of the pavement remains always no less than -6.7°C (20°F).

Rutting was measured every 10,000 load repetitions. The rutting at the terminal stage (at the end of 80,000 repetitions) is summarized in Table 5.7. Values are shown for each of the four mixes at the west, middle, and east transverse profile locations. The last column in Table 5.7 gives the average of the final rutting for each mix.

Table 5.7 Summary of Rutting (in.)

	West	Middle	East	Average
Control Sections:				
- Mix 1 (BM-2C)	0.91	0.83	1.02	0.92
- Mix 2 (SM-2C, 20% Sand)	0.78	0.60	0.69	0.69
Test Sections:				
- Mix 3 (SM-2C, 30% Sand)	1.14	1.27	1.23	1.21
- Mix 4 (SM-2C, 15% Sand)	0.74	0.82	0.93	0.83

By comparing the final rutting (average from the three locations), it can be noted that, except for the mix with 30% sand, Superpave mixes show less rutting than the Marshall mix. The best performing mix of all four sections is Mix 2, indicating that 20% ratio is the optimum sand content in these Superpave mixes. On the other hand, 30% ratio is the worst sand content and resulted in the most rutting (unacceptable, more than one inch).

When comparing each of the pair of sections tested side-by-side, the following may be concluded:

- The best performing Superpave mix (Mix 2) shows a final rutting of 75% of the adjacent BM-2C mix (Mix 1), a typical common Marshall mix used in Kansas.

- The worst performing Superpave mix (Mix 3) shows a final rutting of about 1.5 times the corresponding mix (Mix 4), which suggests that 30% sand is excessive and not recommended.

Looking at the four sections all together, it can be concluded that:

- When adequately designed, Superpave mixes perform better than Marshall mixes.

- The optimum sand content is 20%, which results in about an 18 mm (0.7 in.) rut.

- For a ratio of sand 5% less than the optimum (i.e., 15%) rutting is increased by about 20%. Performance is not as good, but is still better than the Marshall mix.

- For a ratio of sand 10% more than the optimum (i.e., 30%) rutting is increased by about 75%. Performance is very poor, and rut is significantly worse than even the conventional Marshall mix.

It should be noted that actual service life of similar pavements on the highway will

be much longer than the one experienced in the accelerated testing environment. The frequency of occurrence of high axle-loads being applied exactly on the same path and at the rate of 10 repetitions per minute (600 repetitions per hour) is higher than normal traffic conditions. Even on heavy traffic highways, chances are slim that the same type of load axles will hit the exact same spots on the wheel path so frequently. On the other hand, it has been established that the axle of a testing machine (such as that of the K-ATL moving at a speed of 5-7 mph) produces much more damage than those of trucks running at 60 or 70 mph. This is mainly due to the fact that the tires of the slower axles are in contact with the surface at any certain spot along the path much longer than tires of a running truck. These are all characteristics of accelerated pavement testing.

Accelerated pavement testing can give a very good performance assessment when two pavement mixes or pavement types are compared side-by-side. The relative behavior is a good qualitative indication of pavement performance. It gives a general evaluation of how well an alternate design works when compared to a typical design.

Data collected from longitudinal tensile strains below the pavement, soil pressure in the subgrade, asphalt wet densities, material testing, surface elevations and longitudinal profile curves have been collected, properly classified, and documented. Initial analysis of this data did not show a significant trend or pattern for the variation of these parameters as load cycles are applied, or theoretically, damage is indued. However, such data can be used in further research and more detailed analysis. It is made available to future analytical studies and is suitable for comparison with results from numerical modeling and computational methods. For instance, a comparison of the responses computed from the FWD back-calculated layer moduli and the measured responses has been reported by Bhuvanagiri *et al.* [10]. Also they reported attempts to correlate the variation in the longitudinal tensile strains and the vertical compressive stress to possible changes in the AC layer moduli and the modulus of the aggregate base.

The rutting observed in this experiment agree with most of the remarks made by the surrogate study and reported in Bhuvanagiri *et al.* [10]. For instance, the statement that “the north section (Mix 3) had a large shear flow of the AC layer material and most of the rutting happened due to this phenomenon” is true. Also, it is correct to indicate that “it appears that the Superpave mixture containing a large amount of river sand was susceptible to plastic shear flow indicating a lack of stability.”

Another conclusion made by Bhuvanagiri *et al.* [10] is that “most of the rutting on the south section (Mix 4) was due to consolidation of the AC and/or other layers since little flow of AC material was evident.” This is not totally true since plastic flow in this section is also quite significant. Consolidation of the AC layer may have taken place, but the observation of the layers’ profiles on the walls of the trenches (such as Figures 5.17 and 5-18) cut in the test sections indicates that no consolidation, compaction, nor settlement of the soil/aggregate base beneath the pavement has

occurred in neither Mix 3 nor Mix 4.

However, the visual inspection of the cores in all four sections led to a general observation of a reduction in the thickness of the asphalt concrete layer between the core taken off the wheel paths and those taken from within the wheel paths. This reduction generally corresponds to the degree of rutting observed at the surface of the pavement.

APPENDIX A

SUPERPAVE MIX DESIGNS

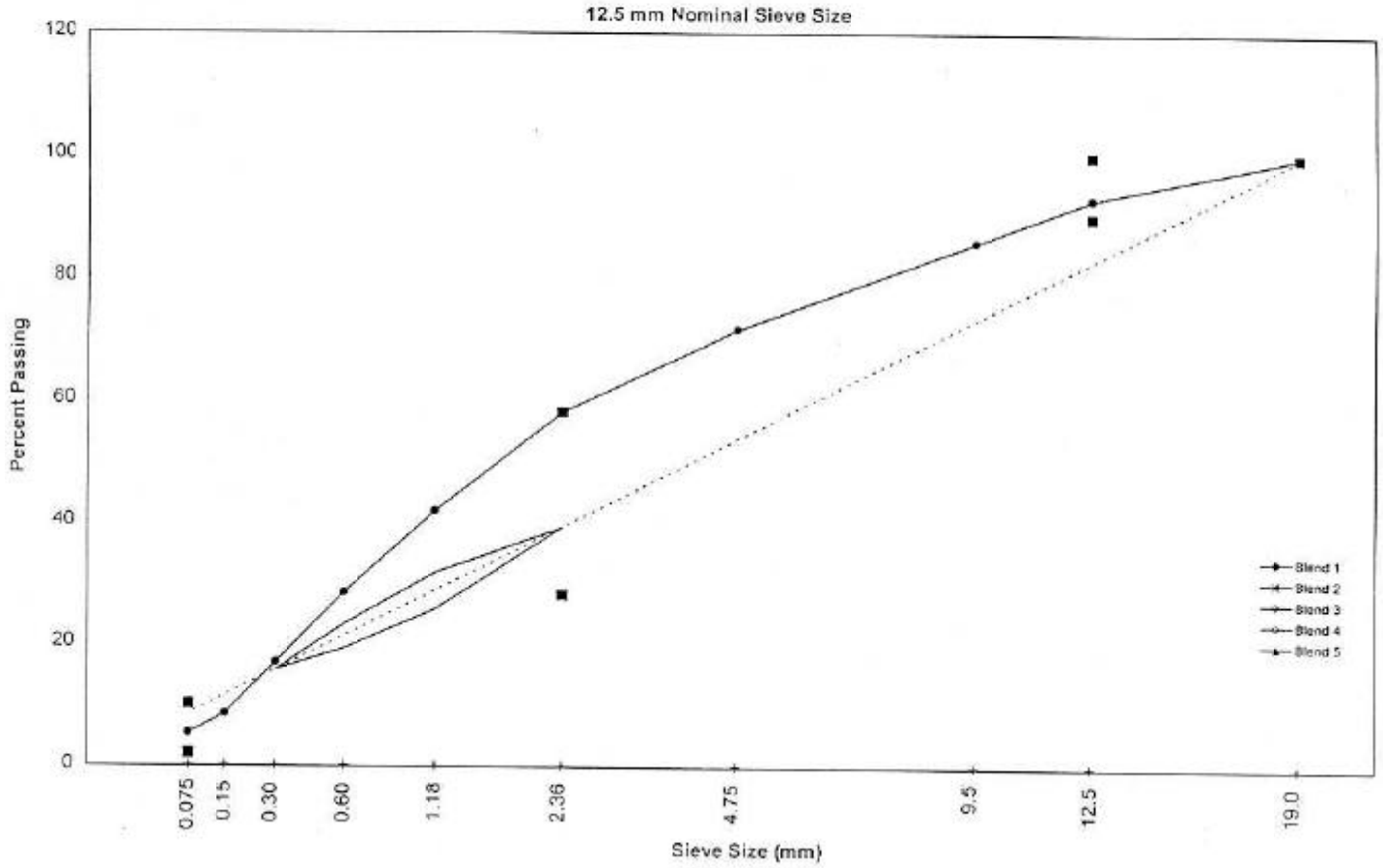
20% Sand + 4" + 8 ft wide, No instrumentation, North Pit.

Aggregate Gradation Trials

SM-2A

Project Name: ATL CONTROL MIS
Technician: GLENN FAGER
Date: 8/28/98

Filename: PINE1251
Description: C
Nominal Sieve Size: 12.5 mm



Aggregate Gradation Trials

Project Name: ATL CONTROL MIS
Technician: GLENN FAGER
Date: 8/28/98

Filename: PINE1251
Description:
Nominal Sieve Size: 12.5 mm

Sieve Size	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5
19.00	100.0				
12.50	93.0				
9.50	85.9				
4.75	71.6				
2.36	58.0				
1.18	41.8				
0.60	28.3				
0.30	16.7				
0.150	8.3				
0.075	5.2				

						Specs.
Gsb						
Gsa						
% Absorption						
Sand Equiv.						40% min.
%Flat and Elongated Particles						---
%Fine Ag. Ang.						---% min
%Course Agg. Ang. (1 or more)						55% min
%Course Agg. Ang. (2 or more)						---% min
Va (assumed)	4.0	4.0	4.0	4.0	4.0	
Pb (assumed)	5.0	5.0	5.0	5.0	5.0	
Gse (est.)						
Ws						
Vba (est.)						
Vbe (est.)	0.102	0.102	0.102	0.102	0.102	
Pbi (est.)						

Absorption Multiplier Gb	
Traffic (million ESAL's)	
Depth from Surface (mm)	

Control Mix

KANSAS DEPARTMENT OF TRANSPORTATION
SUPERPAVE (LEVEL 1) RESULTS

Lab #: 1G98006
)ntract #: 597136071
. roject: 99 K-6733-01
Mix Designation: SM-2A
Spec.: QCQA
Asp.Source & Gr.: COASTAL PG 58-28
Traffic (ESAL'S): .3 - 1

Design Gyrations: 76
Final Gyrations: 117
County: WABAUNSEE
Field Off.: EMPORIA
Contractor: SHILLING CONST. CO.
Producer: SHILLING CONST.
Date Rec./Rep.: 7/07/98 : 7/09/98

Metric Conv.	37.5 mm 1 1/2	25 mm 1	19 mm 3/4	12.5 mm 1/2	9.5 mm 3/8	4.75 mm 4	2.36 mm 8	1.18 mm 16	600 um 30	300 um 50	150 um 100	75 um 200
Job Mix Spec. Band			 0	0 10	10 min		42 61	68 max	77 max	84 max		90.0 98.0
Job Mix Sing.Pt.												
Superpave Grad.			0	7	14	28	43	58	72	83		95.0

Test Data			
Range Tested (% AC)	Increment (% AC)	Superpave Mixing Temperature Range(C)	Superpave Compaction Temperature Range(C)
6.00 to 6.80	0.2666	144 to 150	133 to 138

Operating Range for Hot Mix Plant 133 to 150 (C)

EVALUATION OF TEST RESULTS					RECOMMEND
Asph Cont. %	6.00	6.20	6.50	6.80	6.20
Air Voids (4.00)					3.90
VFA(>=65% <=78%)					73.20
VMA (Min. 14%)					14.60
Density (KG/M3) (Peak +/- 0.5%)					2329
TSR (Min. 80%)					83.75

Values at Recommended Asphalt Content

Filler/Binder Ratio: 1.10
Nom. Max. Agg Size: 12.5
Max.Sp.Gr.: 2.399
Additive:
Sand Equivalent: 84
Theo.Max.Density: 2399

ield Engineer (2)
istrict Engineer
ureau of Construction & Maintenance
ureau of Materials & Research (2)
e rials & Research Center (1)
. Metro Materials (1)
roducer
ile

District Materials Engineer

KANSAS DEPARTMENT OF TRANSPORTATION

SUPERPAVE (LEVEL I) RESULTS

Lab # 16960S2
Contract #
Project: 99K6733-01
Mix Designation: SM-2A
Special Provisions: QC/QA
Asphalt Source & Grade: Neste PG 58-28
Traffic (ESAL'S) 1.0

Design Gyrations: 76
Final Gyrations: 117
County: Wabaunsee
Field Engineer:
Contractor: Shilling Construction Co, Inc.
Producer: Shilling Construction Co, Inc.
Date Rec./Rep.:

	37.5 mm 1 1/2 in	25 mm 1 in	19 mm 3/4 in	12.5 mm 1/2 in	9.5 mm 3/8 in	4.75 mm #4	2.36 mm #8	1.18 mm #16	600 mm #30	300 mm #50	150 mm #100	75 mm #200
Job Mix Spec Band			0	0-10	10 min		42-61	68max	77max	84max		90-98
Job Mix Sing. Point												
Superpave Gradation				7	14	28	43	58	72	83		95

Test Data

Range Tested (%AC)	Increment (%AC)	Superpave Mixing Temperature Range (C)	Superpave Compaction Temperature Range (C)
6.0 to ~~7.6~~ 6.8	0.3	142 - 148	135 - 141

Operating Range for Hot Mix Plant (C) 135 - 148

Evaluation of Test Results

Asphalt Content	6.0	6.2	6.5	6.8	Recommended 6.2
Air Voids (4 +/- 2)	4.4	3.9	3.2	1.5	3.9
VFA (>/= 65%, <80%)	70.5	73.3	78.2	89.6	~~73.4~~ 73.2
VMA (Min. 14%)	14.9	14.6	14.7	14.4	~~14.5~~ 14.6
Density (KG/M3) (Peak +/- 0.5%)	2318	2329	2331	2346	~~2336~~ 2329
TSR (Min. 80%)		84			84

Values at Recommended Asphalt Content:

Filler/Binder Ratio: ~~1.2~~ 1.1
Nom. Max. Agg. Size.: ~~19.0~~ 12.5
Max. Spec. Grav.: ~~2.407~~ 2.399

Sand Equivalent: 84
Theo. Max. Density: ~~149.8~~ 2.399

Date submitted 6-3-98

District Materials Engineer

Kansas Department of Transportaion

Superpave Asphalt Mixture Design and Analysis

Date: 6/3/98

Project# 99K6733-01

Mix Type: SM-2A

Nominal Maximum Aggregate Size: 19mm
Estimated Single Axle Load's: .3 - 1
Average Design High Temperature: 38 C
Depth from Surface: 50 mm

Mineral Aggregate Consensus Properties	Required	Actual	Method
1) Coarse Aggregate Angularity	NA		KT-31
2) Fine Aggregate Angularity	>40	43.5	KT-50
3) Flat, Elongated Particles	<10%	6%, 8%	KT-59
4) Sand Equivalent	>40	84	KT-55

Gradation

Method KT-2

	Control Points: Max.	Control Points: Min.	Resticted Zone Boundry Max.	Resticted Zone Boundry Min	Single Points Required	Single Points Actual
25mm		0				
19mm	10	0				
12.5mm						77.3
9.5mm						14
4.75mm						28
2.36mm	72	42	60.9	60.9		43
1.18mm			68.4	74.4		58
0.600µm			76.9	80.9		72
0.300µm			84.5	84.5		83
0.150µm						92
0.075µm	98	90				95

Asphalt Mix	Required	Actual	Method
1) Gyratory Initial	7		
2) Gyratory Design	76		
3) Gyratory Maximum	117		
4) Dust (filler/binder ratio)	0.6-1.2	1.2	KT-3
5) Voids in Mineral Aggregate (VMA)	>14	14.5	KT-58
6) Voids Filled with Asphalt (VFA)	65-78%	73.8	KT-58
7) Lottman			
Air Voids	7+-1	6.77	KT-56
Saturation	55-80	56.2	
Tensile Strentgh Ratio	>80%	84	

Agg. gate Gradation Trials

Project Name: SM-2A Wab
Technician: DWS
Date: 4/28/98

Filename: SM-2A Wab Trial 1
Description:
Nominal Sieve Size: 12.5 mm

	X Blend 1	Blend 2	Blend 3	Blend 4	Blend 5
Dust	2.0				
SSG-1	20.0				
CS-1	28.0				
CS-2	15.0				
CS-2A	35.0				
	100.00	0.00	0.00	0.00	0.00

Sieve Size	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5	Specs.
19.00	100.0	0.0	0.0	0.0	0.0	
12.50	93.0	0.0	0.0	0.0	0.0	90-100
9.50	85.9	0.0	0.0	0.0	0.0	90 max
4.75	71.6	0.0	0.0	0.0	0.0	
2.36	58.0	0.0	0.0	0.0	0.0	35-58
1.18	41.8	0.0	0.0	0.0	0.0	32 min
0.60	28.3	0.0	0.0	0.0	0.0	23 min
0.30	16.7	0.0	0.0	0.0	0.0	16 min
0.150	8.3	0.0	0.0	0.0	0.0	
0.075	5.2	0.0	0.0	0.0	0.0	2-10

	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5	Specs.
Gsb	2.531					
Gsa	2.640					
% Absorption	1.98					
Sand Equiv.						40% min.
%Flat and Elongated Particles						—
%Fine Ag. Ang.						40% min
%Course Agg. Ang. (1 or more)						65% min
%Course Agg. Ang. (2 or more)						—% min
Va (assumed)	4.0	4.0	4.0	4.0	4.0	
Pb (assumed)	5.0	5.0	5.0	5.0	5.0	
Gse (est.)	2.618					
Ws	2.215					
Vba (est.)	0.029					
Vbe (est.)	0.102	0.102	0.102	0.102	0.102	
Pbi (est.)	5.7					

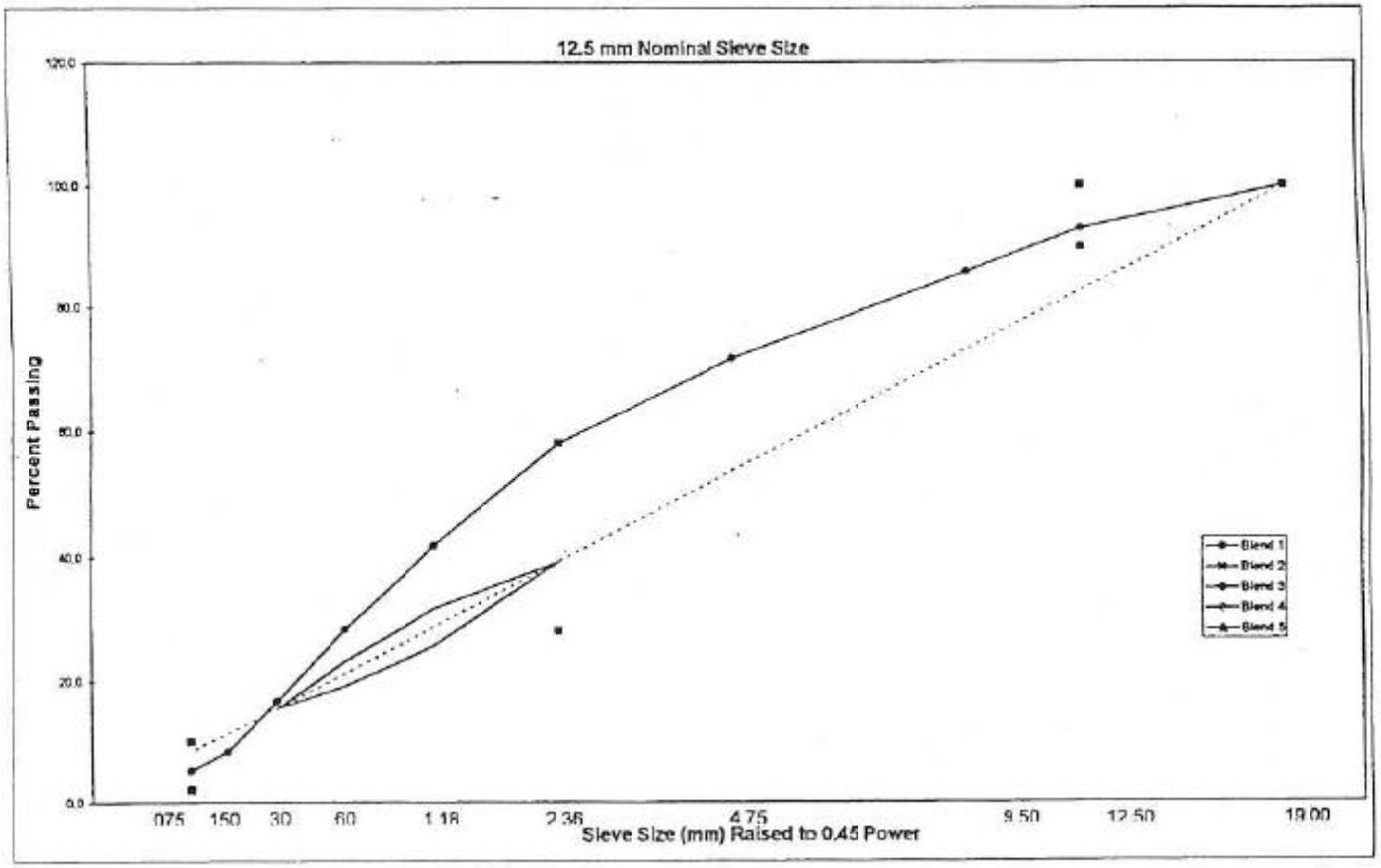
	Wamego Wab Pit				CA-5 Martin-M Zendale	CS-2 Martin-M Zendale	Chat Bingham Drag sand
	Stockpiles						
	Dust	SSG-1			CS-1	CS-2	CS-2A
	100.0	100.0			100.0	100.0	100.0
	100.0	100.0			75.0	100.0	100.0
	100.0	100.0			50.0	99.0	100.0
	100.0	100.0			13.0	73.0	100.0
	100.0	99.0			4.0	52.0	78.0
	100.0	85.0			3.0	37.0	47.0
	99.0	60.0			2.0	29.0	27.0
	92.0	28.0			2.0	23.0	15.0
	73.0	5.0			2.0	19.0	7.0
	58.0	1.0			2.0	16.0	2.5
	2.747	2.602			2.510	2.602	2.470
	2.747	2.609			2.660	2.681	2.620
	4.00	0.44			2.35	2.35	2.30

Absorption Multiplier	0.80
Gb	1.024
Traffic (million ESAL's)	0.9
Depth from Surface (mm)	50.0

Agg. ate Gradation Trials

Project Name: SM-2A Wab
Technician: DWS
Date: 4/28/98

Filename: SM-2A Wab Trial 1
Description: 0
Nominal Sieve Size: 12.5 mm



Mixture Summary Report for Trial Aggregate Blend Analysis

Project Name:	SM-2A Wab Project 1	**N Initial:**	7
Workbook Name:	SM-2A Wab Project 1	**N Design:**	75
Technician:	FES/GFW	**N Max:**	117
Date:	5/20/98	**Nom. Sieve Size:**	12.5 mm
Asphalt Grade:	58-22	**Compaction Temperature:**	148 °C
		Mixture Temperature:	136°C
Design ESAL's (millions):	1	**Depth from Surface (mm):**	50
Design Temperature:	38°C	**Mold Size:**	150 mm

Property	Results				Criteria
	B1V6.0	B1V6.5	B1V6.8	B1V6.2	
%AC	6.0	6.5	6.8	6.2	
%Air Voids (V_a)	4.4	3.3	1.5	3.9	4.0 %
%VMA	14.9	14.8	14.3	14.6	14.0 % Min.
%VFA	70.3	77.9	89.7	73.2	65.0 % Min. 78.0 % Max.
Dust/Asphalt Ratio	1.1	1.1	0.8	1.1	0.6-1.2 %
Max. Specific Gravity (G_{mm})	2.398	2.384	2.361	2.399	
Bulk Specific Gravity (G_{mb})	2.318	2.331	2.346	2.329	
%G_{mm} @ N_{ini}	88.3	89.1	91.4	88.7	89.0 % Max.
%G_{mm} @ N_{max}	96.6	97.8	99.3	97.1	98.0 % Max.
Effective Sp. Gravity of Blend (G_{se})	2.623	2.627	2.610	2.632	---
Sp. Gravity of Binder (G_b)	1.024	1.024	1.024	1.024	---
Sp. Gravity of Aggregate (Gs_b)	2.531	2.531	2.531	2.531	---

Summary Report

Project Name: SM-2A Wab Project 1	N Initial: 7
Workbook Name: SM-2A Wab Project 1	N Design: 76
Technician: FES/GFW	N Max: 117
Date: 5/20/98	Nom. Sieve Size: 12.5mm
Asphalt Grade: 58-22	Design Temperature: 38°C
Compaction Temp: 148°C	Design ESAL's (millions): 1

Blend	%AC	%Gmm @ N = 7 (corrected)	%Gmm @ N = 76 (corrected)	%Gmm @ N = 117 (corrected)	%Air Voids @ NDesign	%VMA @ NDesign
B1V6.0	6.0	88.3	95.6	96.6	4.4	14.9
B1V6.5	6.5	89.1	96.7	97.8	3.3	14.8
B1V6.8	6.8	91.4	98.5	99.3	1.5	14.3
B1V6.2	6.2	88.7	96.1	97.1	3.9	14.6

Blend	Estimated %AC @ 4% Va	Estimated %Gmm @ N = 7 (89% Max)	Estimated %Gmm @ N = 76	Estimated %Gmm @ N = 117 (98% Max)	Estimated %VMA @ NDesign (14 % Min)	Estimated %VFA @ NDesign (65-78%)
B1V6.0	6.2	88.7	96.0	97.1	14.8	72.9
B1V6.5	6.2	88.4	96.0	97.0	14.9	73.1
B1V6.8	5.8	88.8	96.0	96.8	14.6	72.6
B1V6.2	6.2	88.7	96.0	97.0	14.6	72.6

	B1V6.0	B1V6.5	B1V6.8	B1V6.2
Ag. Bulk Specific Gravity (Gsb):	2.531	2.531	2.531	2.531
Percent Binder by wt. of mix (Pbi):	6.0	6.5	6.8	6.2
Percent Aggregate (Ps):	94.0	93.5	93.2	93.8
Specific Gravity of Binder (Gb):	1.024	1.024	1.024	1.024
Fines (%Passing 0.075mm Sieve):	5.2	5.7	4.8	5.3
Effective Specific Gravity (Gse):	2.623	2.627	2.610	2.632
Effective % Binder (Pbe):	4.7	5.1	5.7	4.7
Dust Proportion (0.6-1.2%):	1.1	1.1	0.8	1.1

7/6/98, 11:16 AM

i ±: 99K6733-01
Job# :3004

Shiling truction Co, Inc.
555 Poyntz, Suite 260
Manhattan, KS 66502
(785)776-5077
(785)776-4714

Fred Sowr rt.# 1496
Glenn Welsc. rt.# 1517
Barbara Mather Cert.# 1528

KANSAS DEPARTMENT OF TRANSPORTATION

Material	Material Code:	Producer or Pit Name	Legal Description & Official Quality	County
CS-1		Martin-Marietta	SE1/4,S33T10S,R09E	Riley
CS-2A	chat drag sand	Bingham Sand and Gravel	S22,T29N,R23E	Cherokee
CS-2	screening	Martin-Marietta	SE1/4,S33T10S,R09E	Riley
SSG-1	sand	Wamego Sand	S33,T12S,R7E	Wabaunsee

APPENDIX B

BASE LAYER SOIL TEST RESULTS

Kansas Department of Transportation

Report of sample of AB-3

Laboratory No. 98-5066

Date Reported. December 15, 1998

Date Received. 11/23/98

Specification No. Sec. 1105 of 1990 Std. Specs. Quantity - - -

Source of material Shilling Const.

Sample from ATL - Middle Pit

Submitted by Glenn A. Fager, Res. Bit. Engr., 2300 VanBuren, Topeka, Ks.

Identification marks AB-3

Project or POV EN2374-99 ACT803

Type of construction Pavm't Surfacing

TEST RESULTS

Sieve Size	2"	1½"	1"	3/4"	1/2"	3/8"	4	8	10	16	30	40	50	80	100	200
Specificed:	0	0-5		5-30			35-60	45-70				60-84				80-92
Actual:	0	0	9	15	30	41	55	64	66	73	77	79	81	83	84	86

		Specified	Actual
Liquid Limit	=	30 max	23
Plastic Limit	=		14
Plasticity Index	=	2-8	9
Max Dry Density	=		2,053.0 Kg/m3
Opt. Moisture			10%

cc: L.S. Ingram
Glenn A. Fager
J.J. Brennan
Soil Section
File 1-5

Reported by: Monie Hurst for

Title James J. Brennan, Soils Engineer

Rev. 3-76

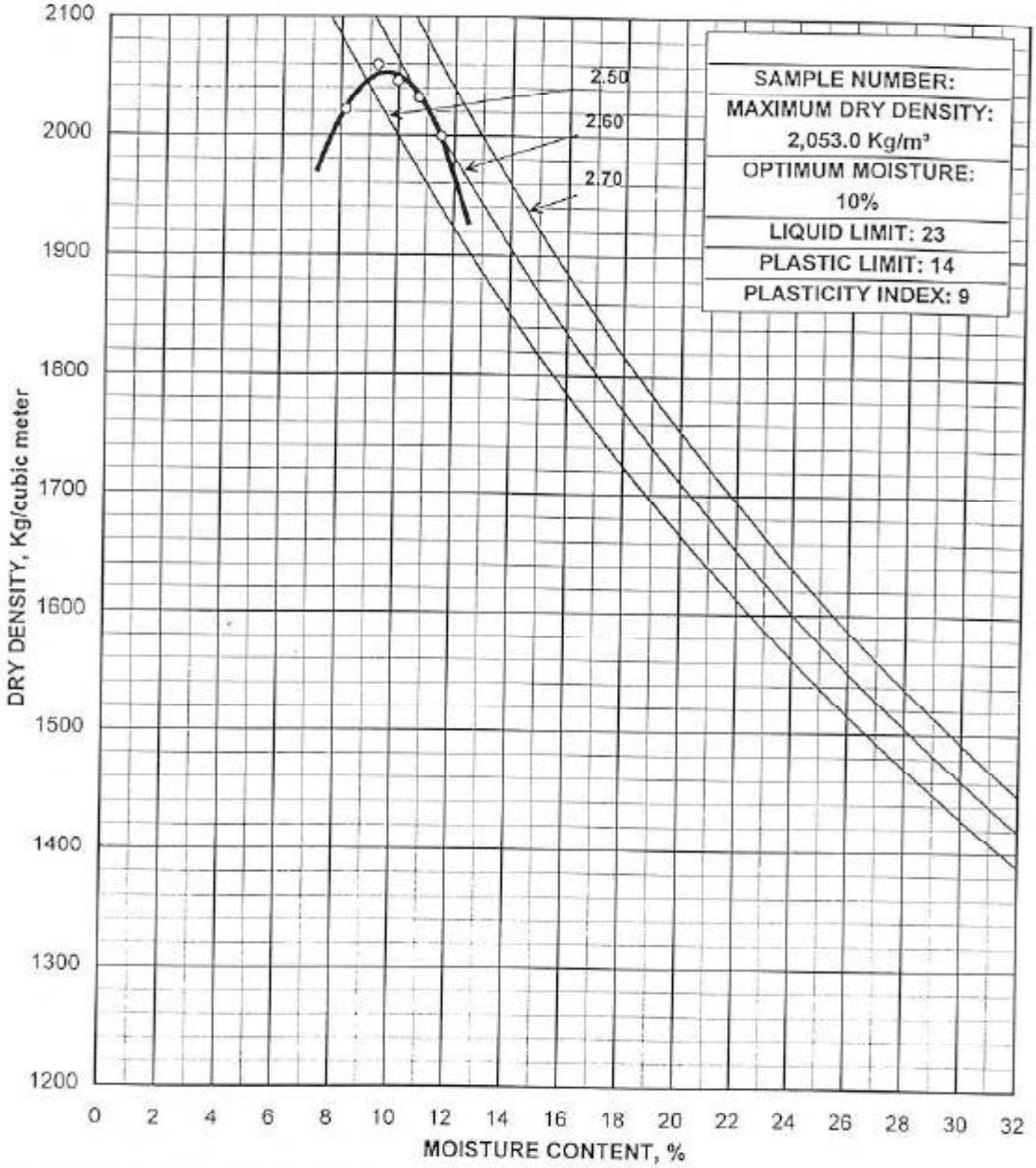
D.O.T. Form 623

KANSAS DEPARTMENT OF TRANSPORTATION

REPORT OF SOIL COMPACTION TESTS

SUBMITTED BY Glenn A Fager, Res. Bit. Engr. ADDRESS _____ LAB. NO 98-5066

PROJECT EN-2374-99 ACT803 COUNTY _____ DATE 12-9-98



TEST METHOD AASHTO T99-93, Method A

REMARKS _____

L. S. Ingram, P.E.

Chief, Bureau of Materials and Research

BY _____

James J. Brennan, Soils Engineer

D.O.T. Form No. 638

APPENDIX C

DATA ACQUISITION SYSTEMS' SETUP

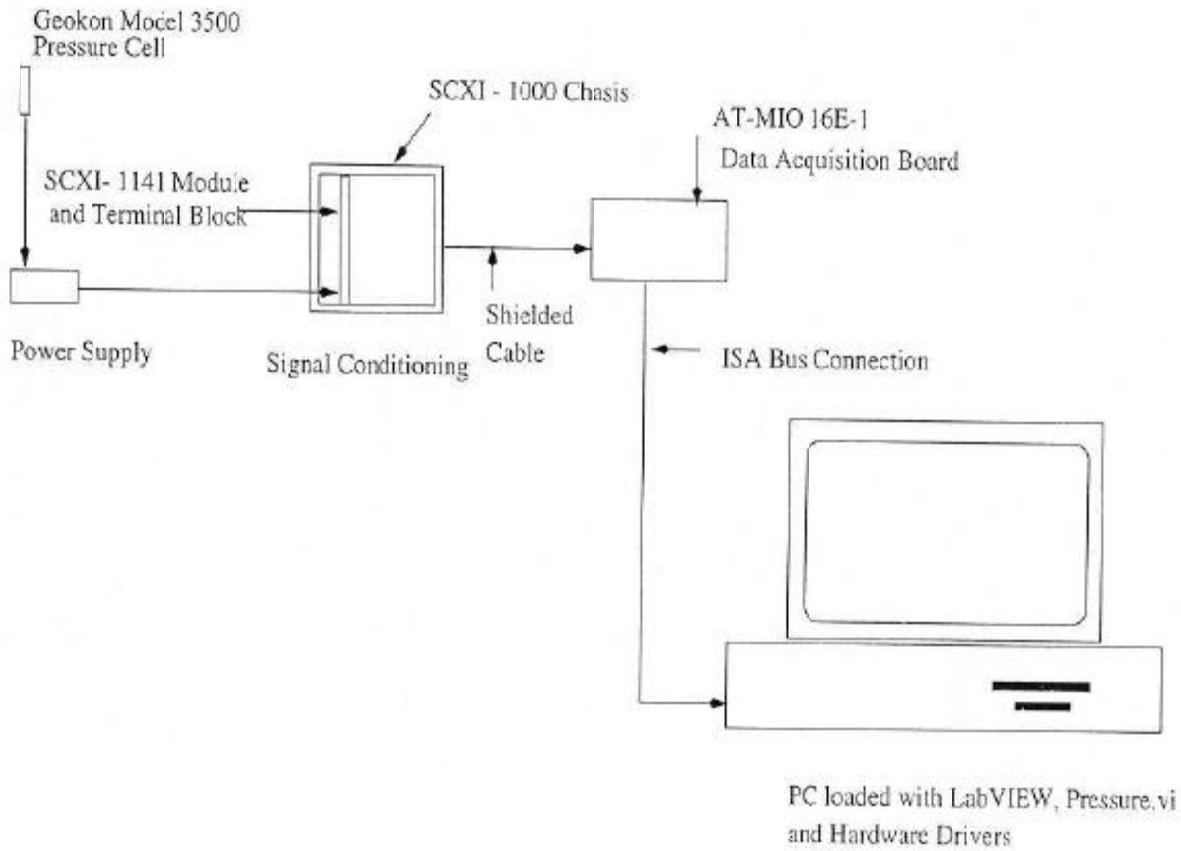


Figure 7: Schematic Representation of Pressure Data Acquisition System

pre1.vi
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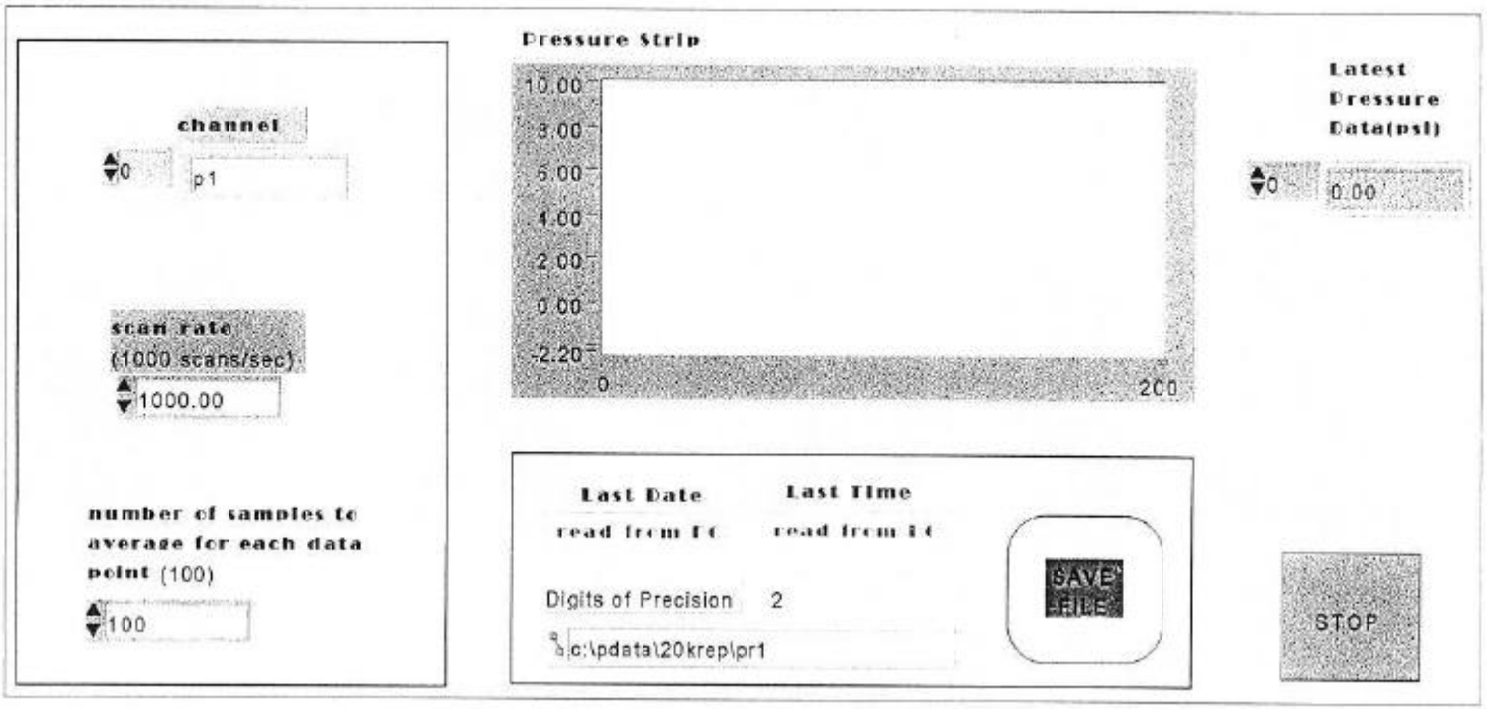

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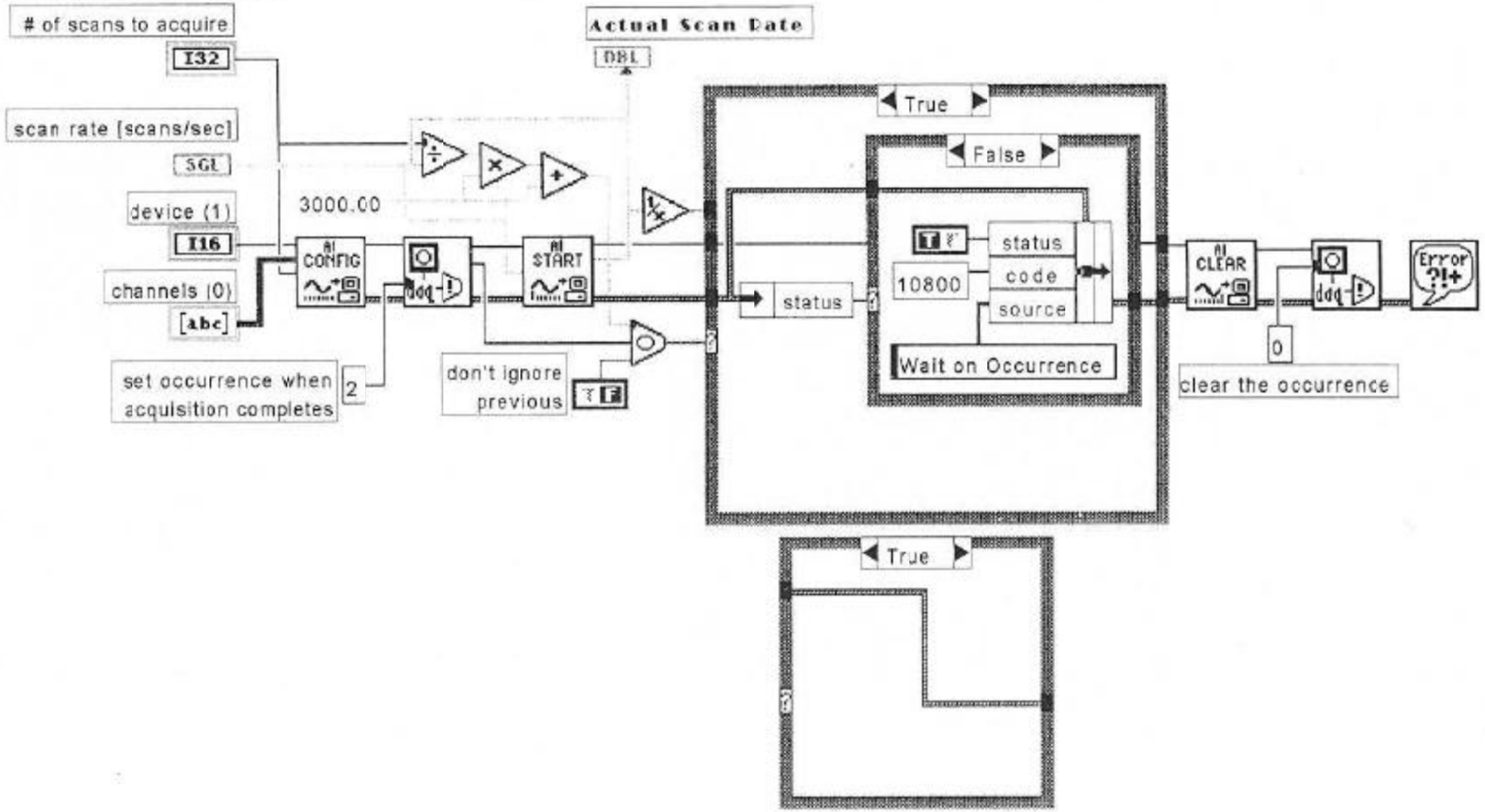

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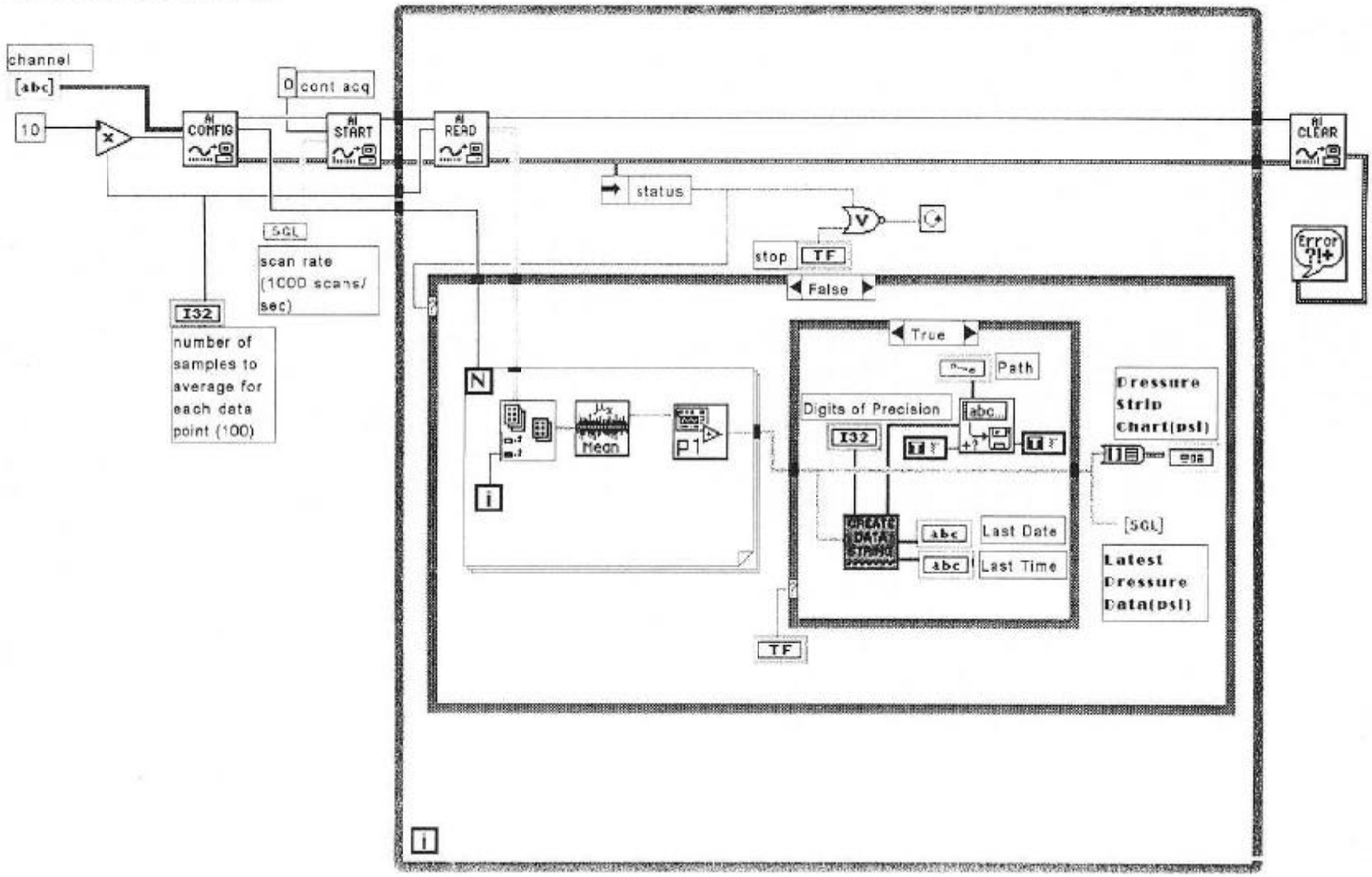

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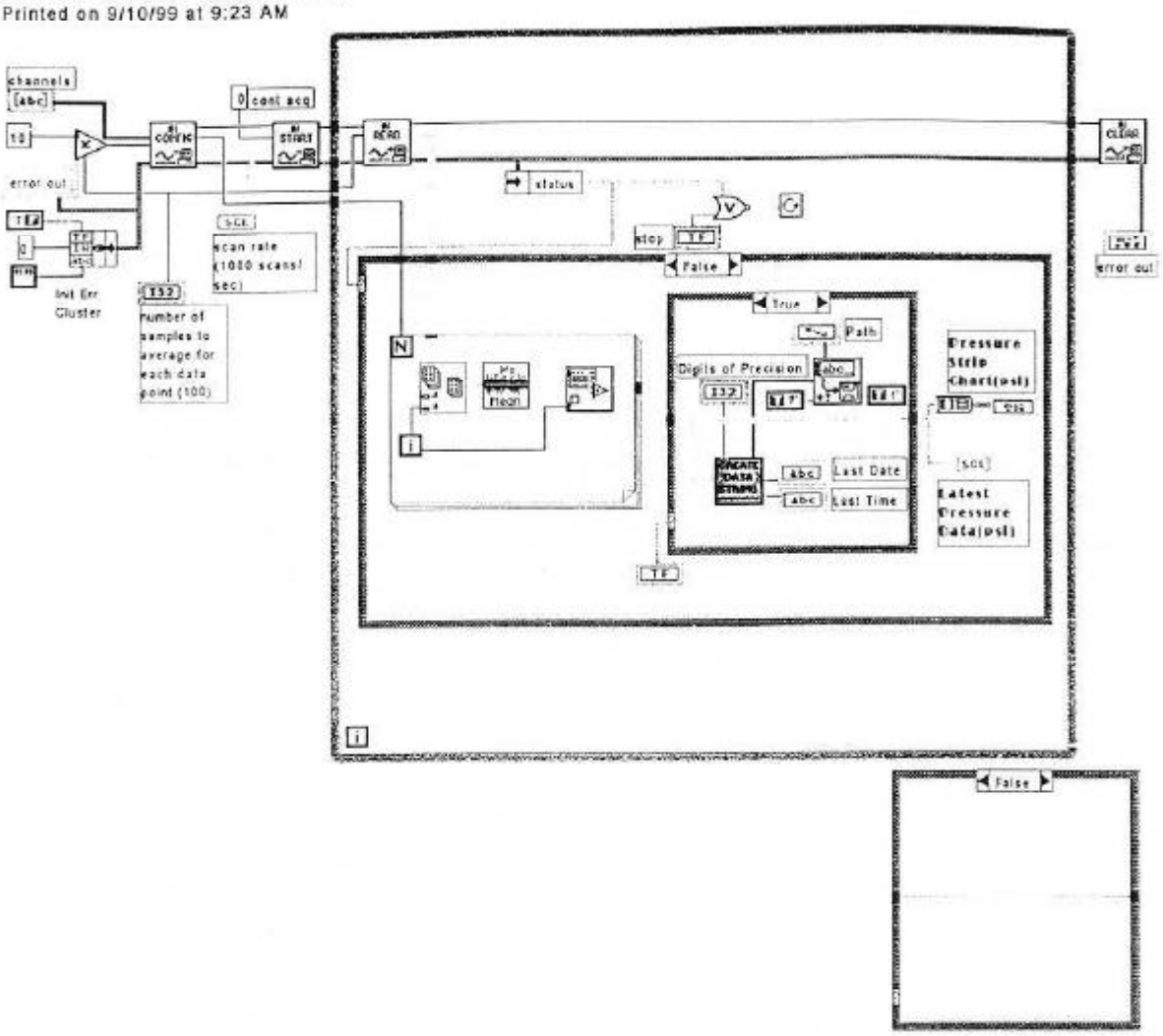

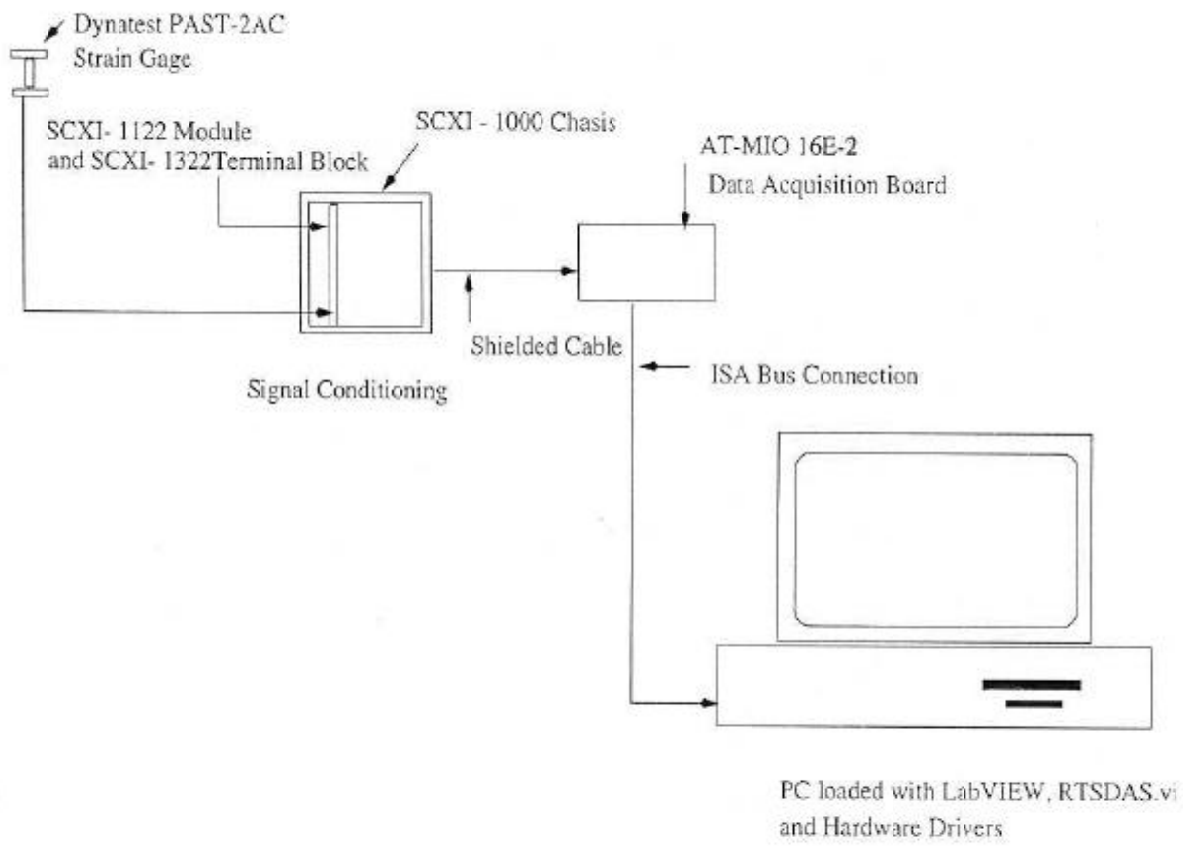

Figure 6: Schematic Representation of Strain Data Acquisition System

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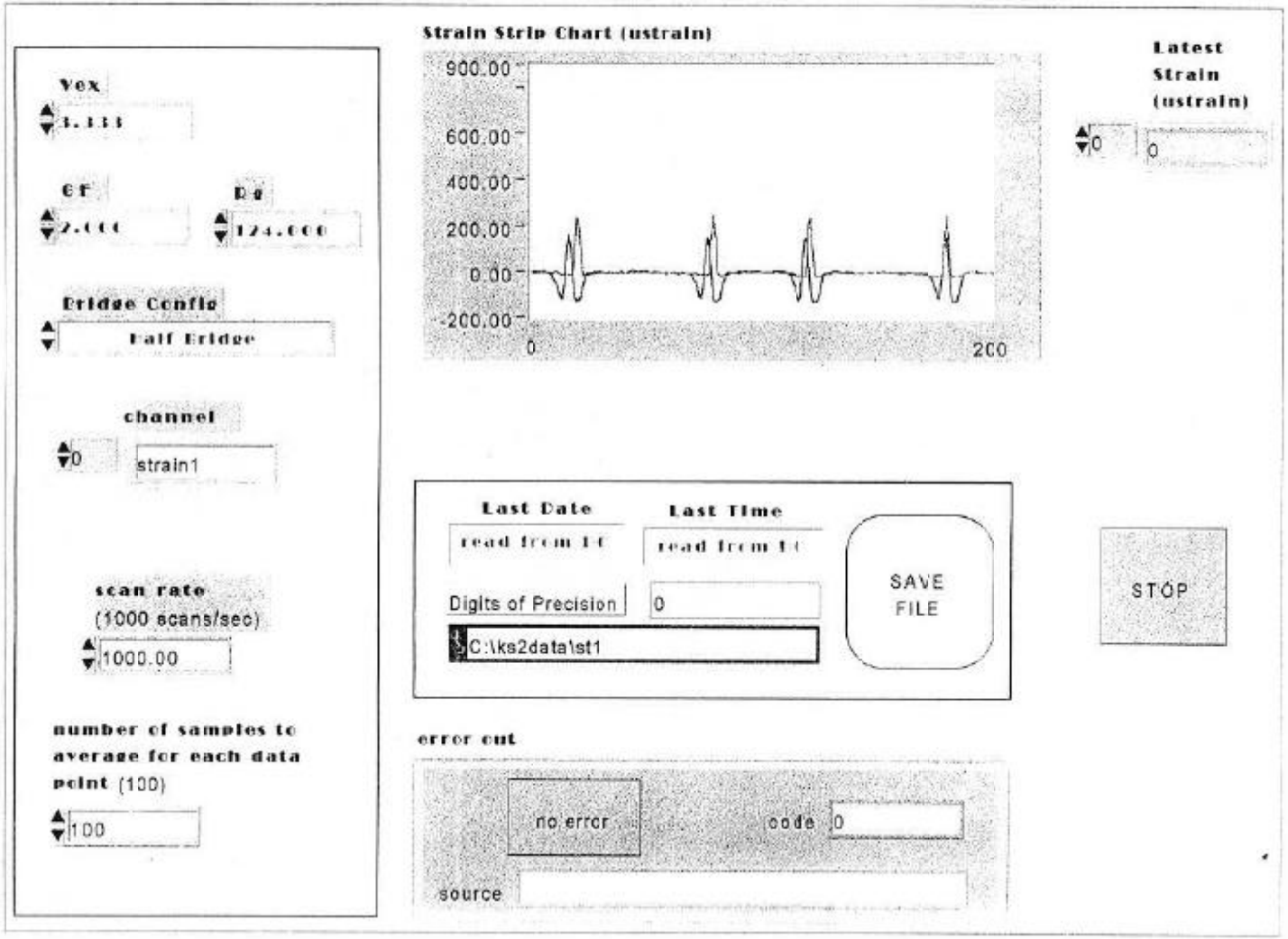

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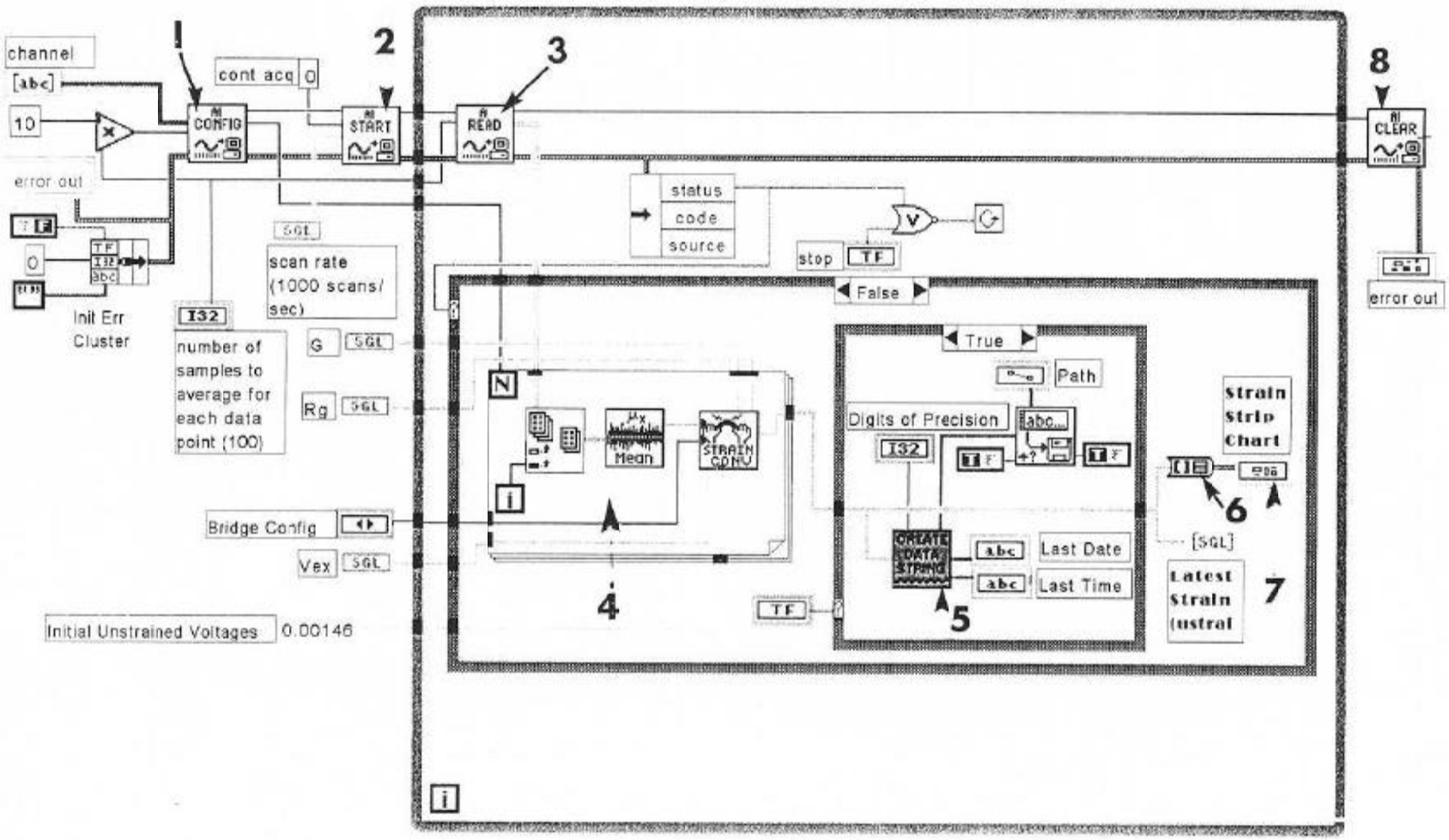

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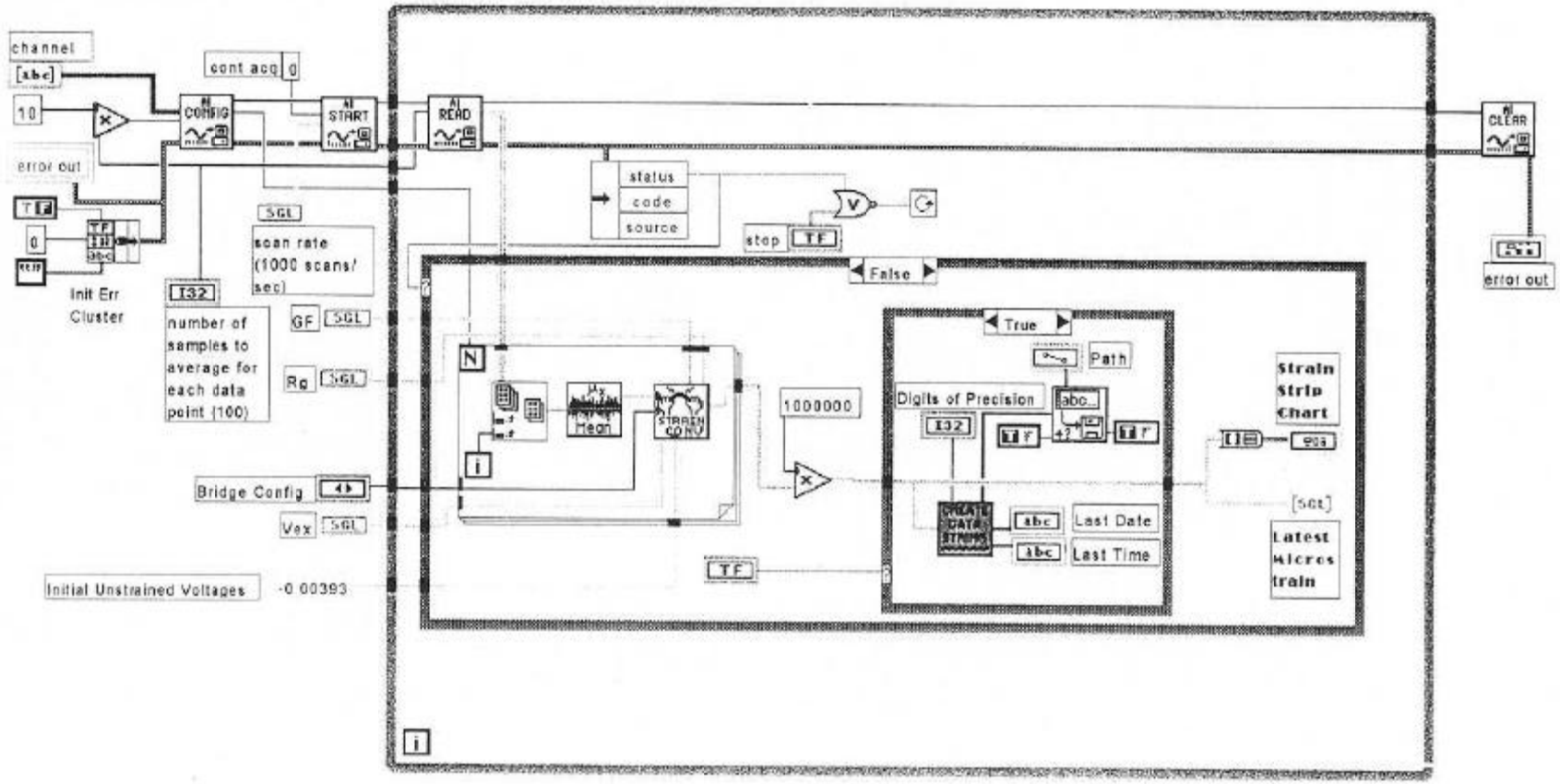

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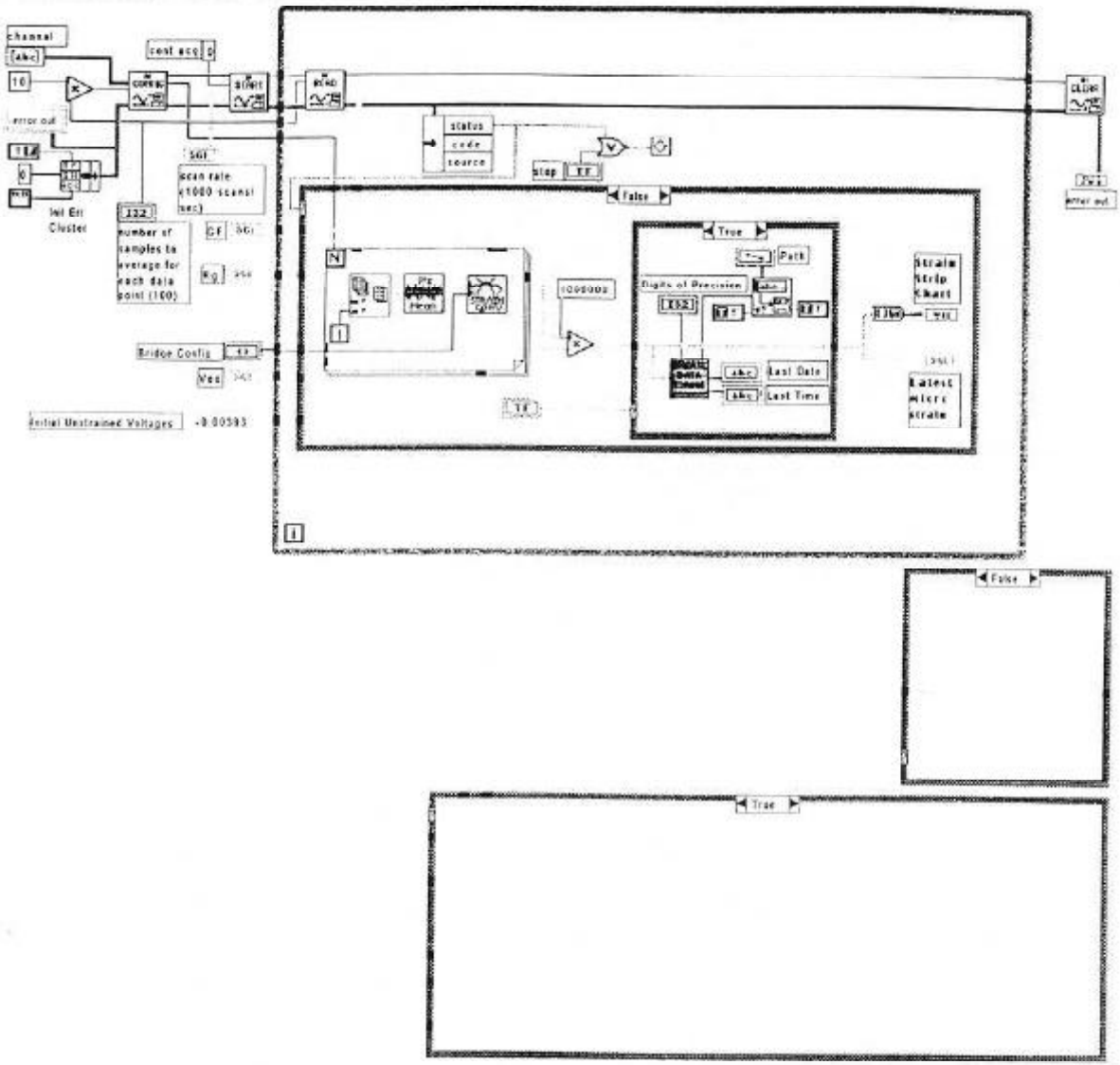

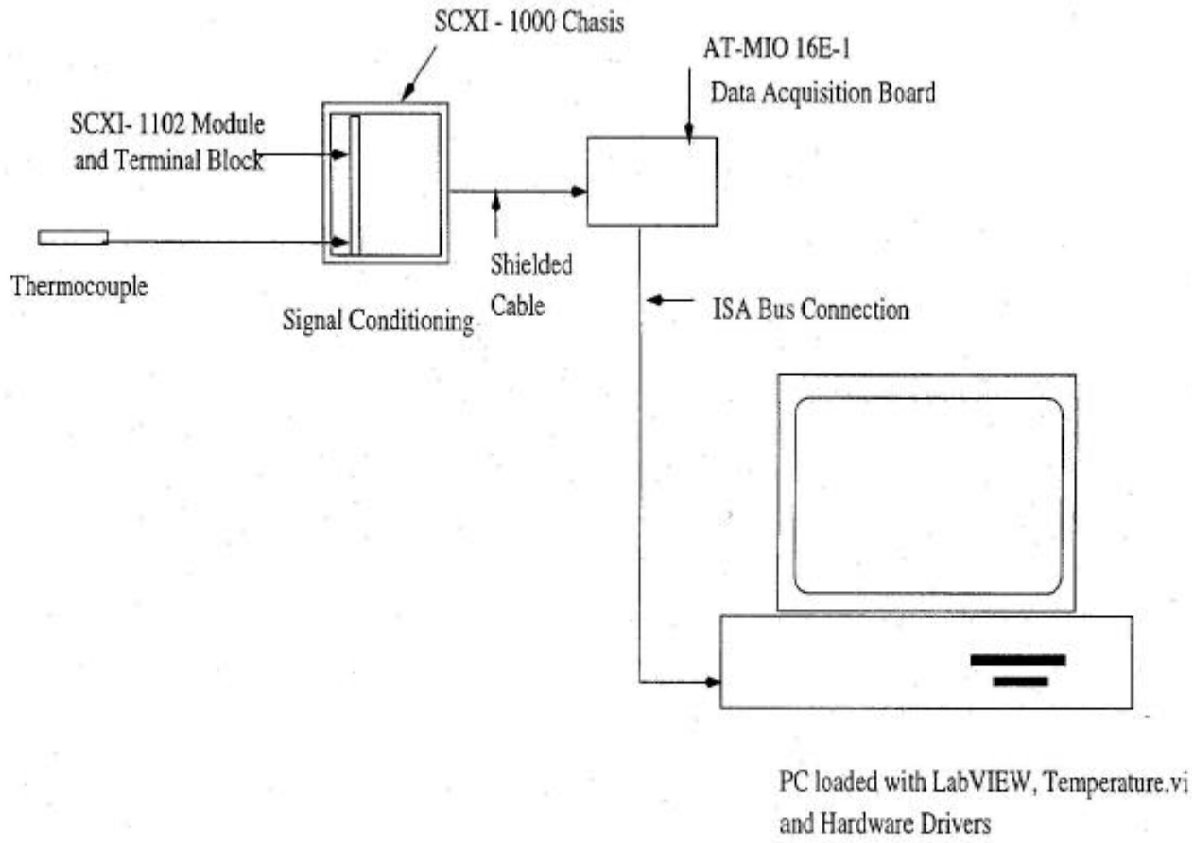

Figure 5: Schematic Representation of Temperature Data Acquisition System

Temp

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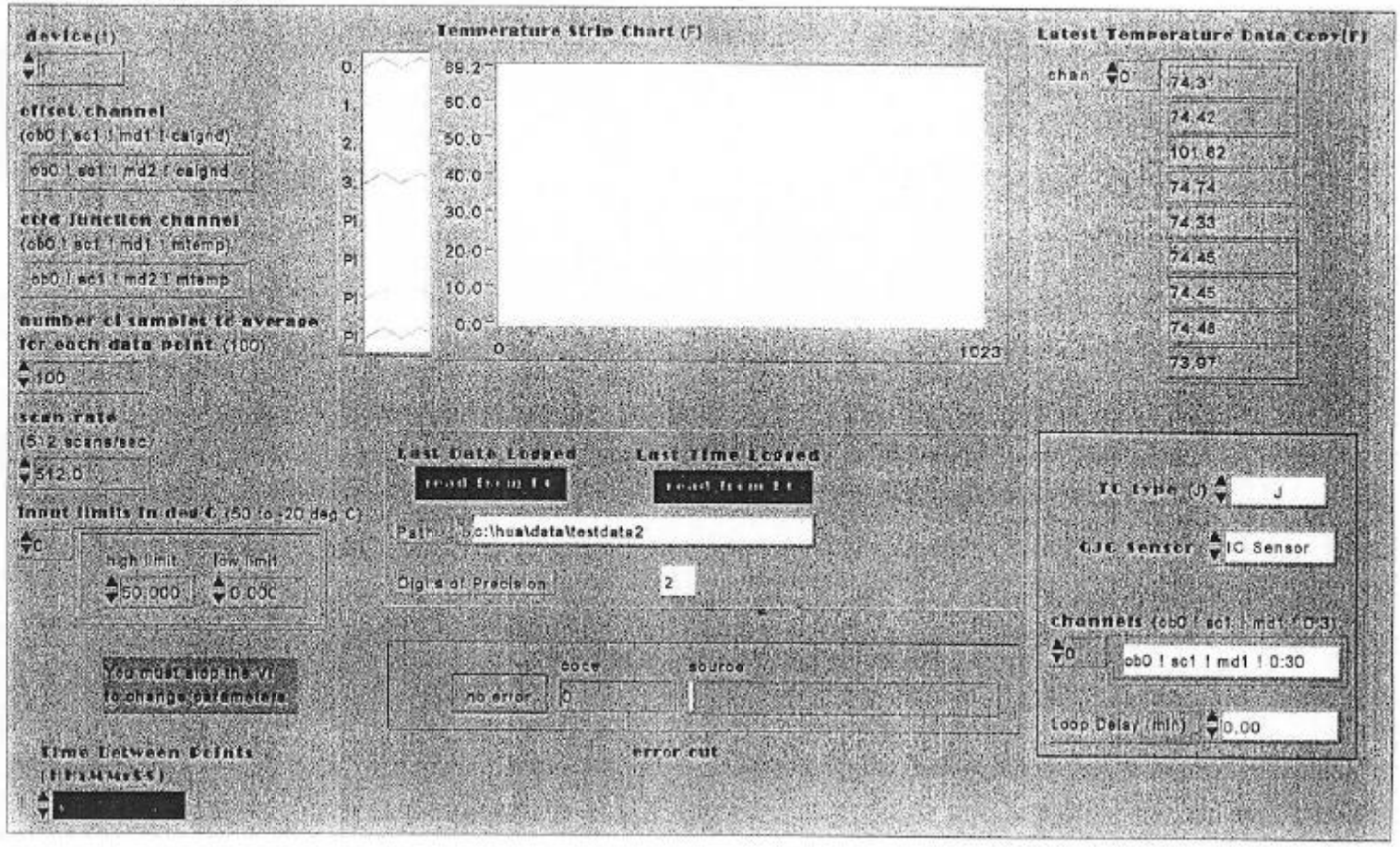
Page 1



SCXI-1102 Thermocouplenew.vi
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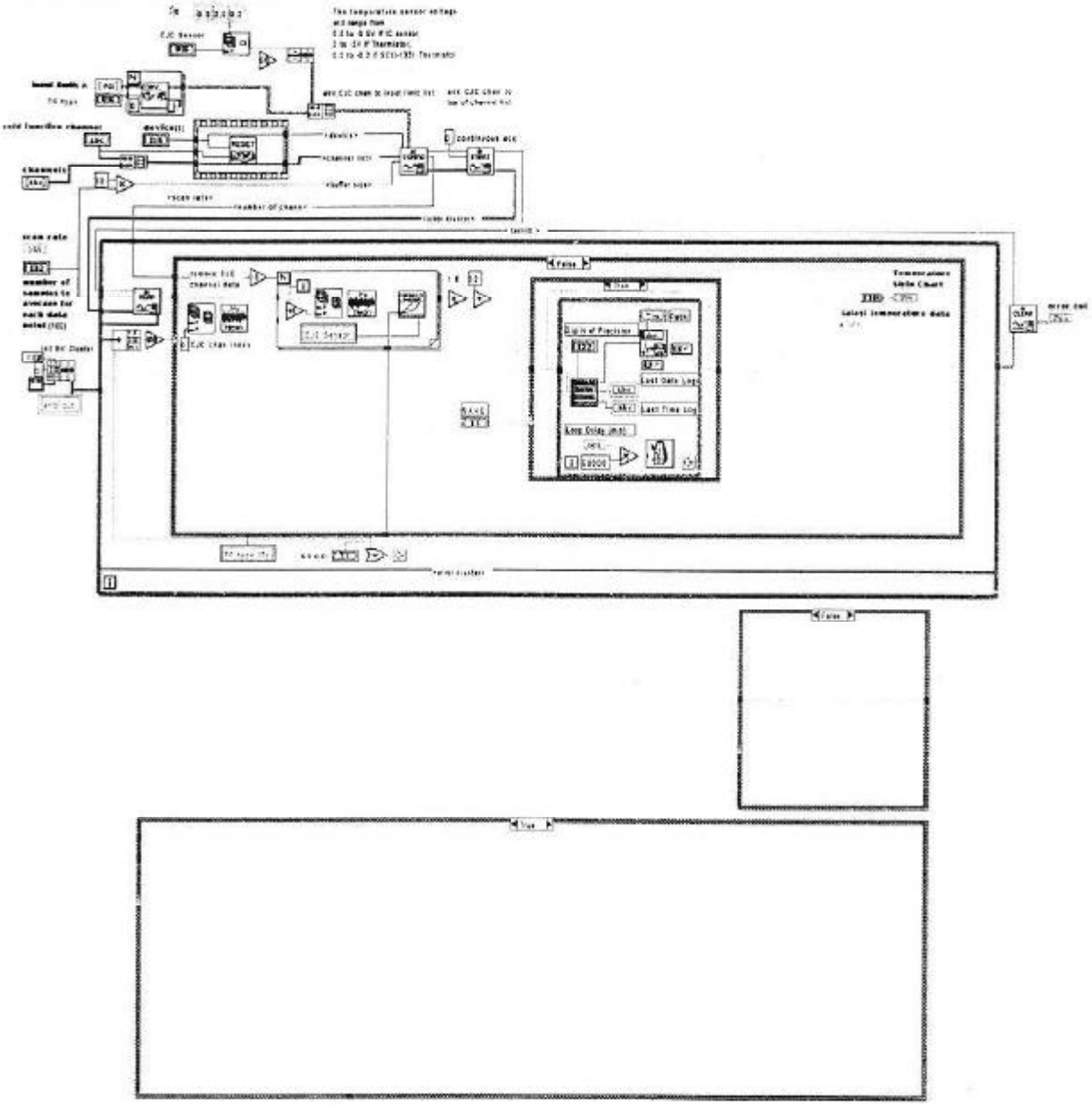

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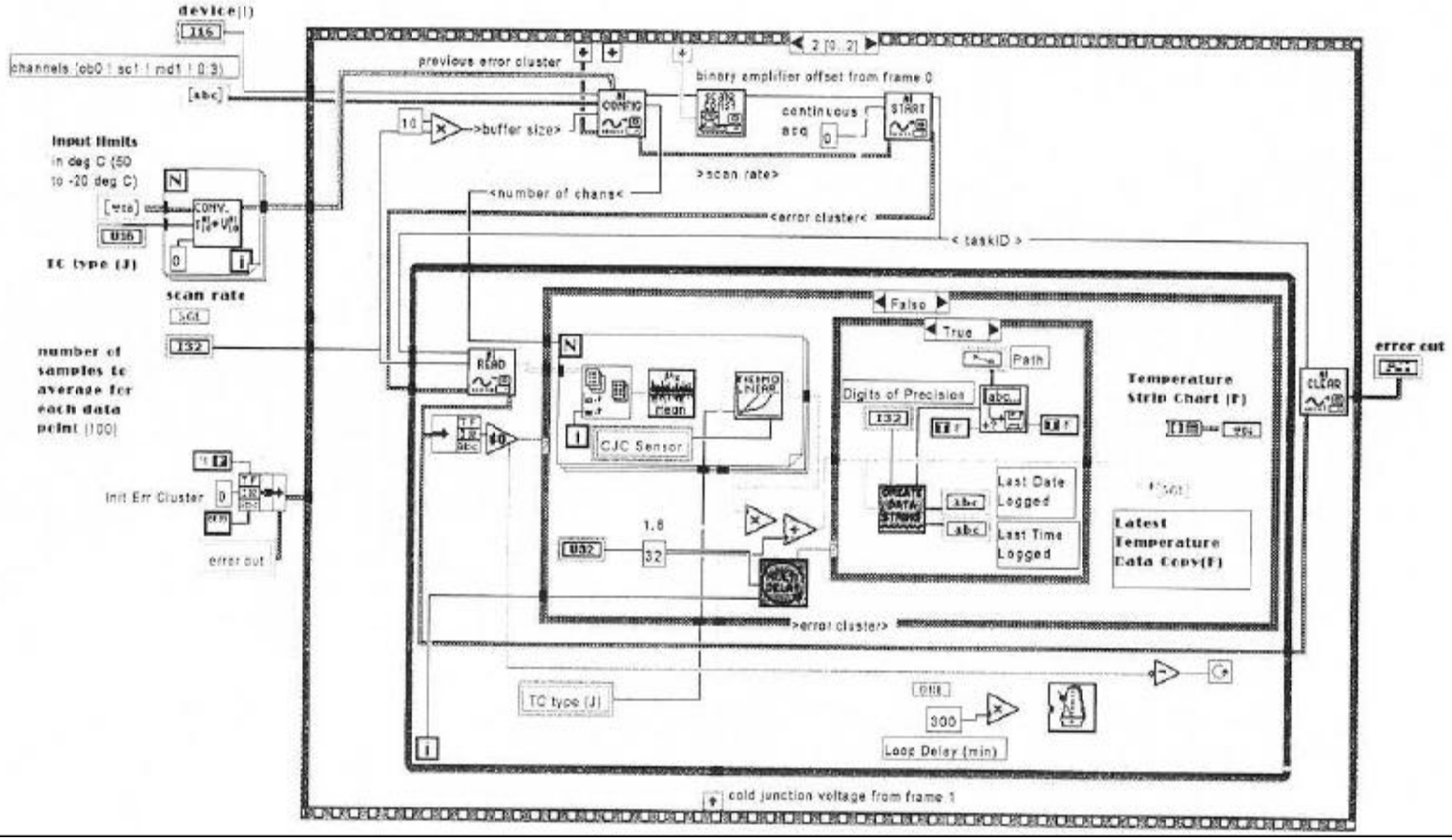

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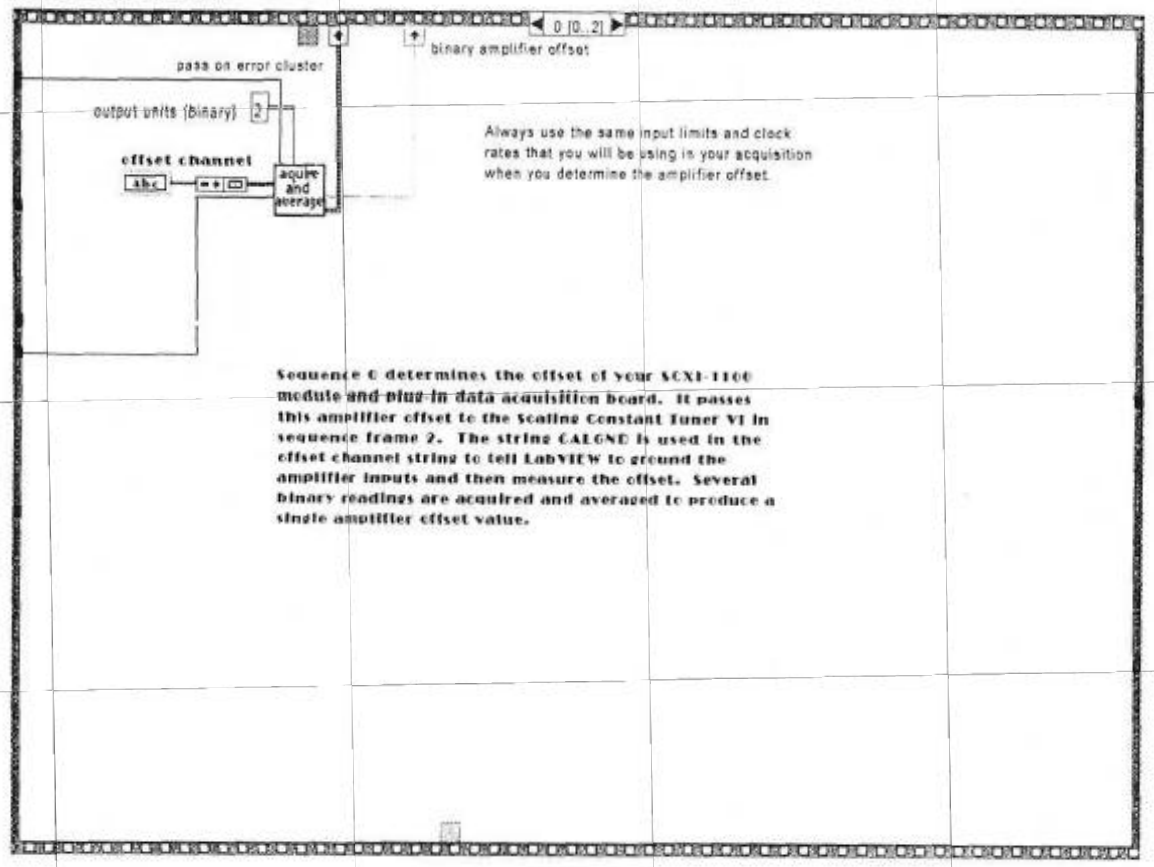

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