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FINAL REPORT PHASE II

PRELIMINARY DESIGN

VERTICAL STORES HANDLING CONVEYOR

RESEARCH AND DEVELOPMENT

CONTRACT NO. N00024-72-C-5500

NAVAL SHIP ENGINEERING CENTER

MATERIAL HANDLING SYSTEMS
KORNYLAK CORPORATION
400 HEATON ST. - HAMILTON, OHIO 45011

MAY 1977

Final Report

Phase II

Detail Design and Preliminary Design Drawings

Research and Development

Contract No.

N00024-72-C-5500

Naval Ship Engineering Center

Preliminary Design, Vertical Stores Handling Conveyor

Submitted By:

KORNYLAK CORPORATION
400 Heaton Street
Hamilton, Ohio 45011

May, 1977

Introduction

The primary purpose of Phase II of Research and Development Contract No. N00024-72-C-5500 was to prepare detailed preliminary design drawings based on the concepts developed and approved in Phase I. Phase II also required the preparation and submittal of:

- a Final Reliability Program,
- a Final Maintainability Program,
- a Failure Modes and Effects Selection Criteria Report,
- a Final Failure Modes and Effects Analysis,
- detailed design calculations,
- various Engineering Studies and Investigations.

Drawings, programs, plans, studies, investigations and reports have been completed and submtted fulfilling all requirements of Phase II.

Distribution

Copies of this Final Report for Phase II of R & D Contract No. N00024-72-C-5500 were distributed by Kornylak Corporation as follows:

Distributed to:	Date	Copies	Reproducibles
Director Defense Documentation Center Cameron Station Alexandria, Virginia 22314 Attn: Code SL4200	May, 1977	20	0
Commander Naval Ship Engineering Center Department of the Navy Code 6164D Washington, D. C. 20362	May, 1977	6	0

Section II

Transmittal Log for Phase II

The following pages comprize a chronological listing of all significant transmittals made by the Kornylak Corporation from the start of Phase II through May 12, 1977. Opposite the "Description" of the transmittal are columns listing the "date of report", "date of transmittal",,to whom the transmittal was sent and appropriate remarks.

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
.Schedule of Work Phase II	04 Nov. 1974	04 Nov. 1974	T.A.Satterthwaite	
.Dwg. #2-1026-P10 Rev. B Loader/Unloader Assy. With Jam Sensing Device		13 Dec. 1974	T.A.Satterthwaite	
.E003 Contract Funds Status Report	30 Oct. 1974	30 Oct. 1974	Various	See Distribution Schedule
.Dwg. #2-1026-P41 Top Overtravel Limit Assy. (Front Loading)		10 Jan. 1975	T.A.Satterthwaite	
.Dwg. #2-1026-P42 Top Overtravel Limit Assy. (Rear Loading)		10 Jan. 1975	T.A.Satterthwaite	
.Dwg. #2-1026-P19 Rev. B Roller Bed Loader/Unloader Assy. with Jam Sensing Device		10 Jan. 1975	T.A.Satterthwaite	
.Dwg. #2-1026-P43 Lubrication Access.		17 Jan. 1975	Commander, NSEC Code 6164	
.E003 Contract Funds Status Report	21 Jan. 1975	21 Jan. 1975	Various	See Distribution Schedule
.E002 Milestone/Cost Report	21 Jan. 1975	21 Jan. 1975	Various	See Distribution Schedule
.E001 Milestone/Cost Plan	21 Jan. 1975	21 Jan. 1975	Various	See Distribution Schedule

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
•Public Voucher II-01	22 Jan. 1975	22 Jan. 1975	Defense Contract Audit Agency Columbus, Ohio	
•Agenda for Design Review Meeting	22 Jan. 1975	22 Jan. 1975	Commander, NSEC Code 6164	
•Final-Reliability and Maintainability Program Plans CDRL Item B001AA	28 Jan. 1975	04 Feb. 1975	Commander, NSEC Code 6164	
•Letter on Design "D" vs. Design "B" type motors	17 March 1975	17 March 1975	Commander, NSEC Code 6164	
•Drawing Lists: 2-1026-DL1 2-1026-DL2 2-1026-DL3 2-1026-DL4 2-1026-DL5 2-1026-DL6 2-1026-DL7 2-1026-DL8 2-1026-DL9 2-1026-DL10 2-1026-DL11 2-1026-DL12 2-1026-DL13 2-1026-DL14 2-1026-DL15 2-1026-DL16 2-1026-DL17 2-1026-DL18	19 March 1975	21 March 1975	Commander, NSEC Code 6164	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
•Letter on brake selection and location	31 March 1975	31 March 1975	Commander, NSEC Code 6164	
•Dwg. #2-1026-SC8 Dwg. #2-1026-SC9 Panel sizing with and without stiffeners		31 March 1975	Commander, NSEC Code 6164	
•Letter on motor speed selection	31 March 1975	31 March 1975	Commander, NSEC Code 6164	
•Letter on various methods for conveyor control and use of 440V for control circuitry	07 April 1975	07 April 1975	Commander, NSEC Code 6164	
•FMEA Selection and Criteria Report CDRL #B001AB	10 April 1975	14 April 1975	Commander, NSEC Code 6164	
•Public Voucher II-02	14 April 1975	14 April 1975	Defense Contract Audit Agency Columbus, Ohio	
•E003 Contract Fund Status Report	14 April 1975	14 April 1975	Various	See Distribution Schedule
•E002 Milestone/Cost Report	14 April 1975	14 April 1975	Various	See Distribution Schedule
•Design Review Meeting minutes CDRL B001AE	1) Dec. 19 & 20, 1974 2) Mar. 3 & 4, 1975	14 April 1975	Commander, NSEC Code 6165	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
.Engineering Progress Report CDRL B001AF	15 April 1975	15 April 1975	Commander, NSEC Code 6164	
----------AS OF 15 APRIL 1975----------				
.Letter making firm contract- or proposal covering con- or controls	27 June 1975	27 June 1975	Commander, NSEC Code 6164	
.Drawing transmittal Drawing #2-1026-P10 Rev.C(1) Drawing #2-1026-P10 Rev.C(2) Drawing #2-1026-SC8 Rev. A Drawing #2-1026-SC9 Rev. A Drawing #2-1026-P20F Drawing #2-1026-P28 Drawing #2-1026-P26 Drawing #2-1026-41F Drawing #2-1026-48F Drawing #2-1026-49F Drawing #2-1026-45F Drawing #2-1026-44F Drawing #2-1026-42F Drawing #2-1026-43F Drawing #2-1026-47F Drawing #2-1026-46F	27 June 1975	27 June 1975	Commander, NSEC Code 6164	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
•Contract Funds Status report (E003)	18 July 1975	18 July 1975	Various	See Distribution Schedule
•Milestone cost report	18 July 1975	18 July 1975	Various	See Distribution Schedule
•Public Vouch #II-03	13 July 1975	18 July 1975	Defense Contract Audit Agency Columbus, Ohio	
•Drawing transmittal	18 July 1975	18 July 1975	Commander, NASCC Code 6164	
Drawing #2-1026-P10F Sht. 1	Rev. D			
Drawing #2-1026-P10R Sht. 2	Rev. D			
Drawing #2-1026-51F				
Drawing #2-1026-52F				
Drawing #2-1026-53F				
Drawing #2-1026-61F				
Drawing #2-1026-54F				
Drawing #2-1026-55F				
Drawing #2-1026-56F				
Drawing #2-1026-59F				
Drawing #2-1026-60F				
Drawing #2-1026-62F				
Drawing #2-1026-63F				
Drawing #2-1026-65F				
Drawing #2-1026-57F				
Drawing #2-1026-58F				
Drawing #2-1026-64F				

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
•Drawing Transmittal Drawing #2-1026-66F Drawing #2-1026-67F Drawing #2-1026-68F Drawing #2-1026-69F Drawing #2-1026-70F	28 July 1975	28 July 1975	Commander, NSEC Code 6164	
•Submittal of DD Form 882	19 Aug. 1975	19 Aug. 1975	E. J. Wahle, Administrative Officer	
•Contractor's proposal for a hardware visualization and concept testing unit.	14 Aug. 1975	14 Aug. 1975	Commander, NSEC Code 6164	
•Contractors proposal for a "push-pull" illuminated switch.	14 Aug. 1975	14 Aug. 1975	Commander, NSEC Code 6164	
•Drawing transmittal Drawing #2-1026-SC8 Drawing #2-1026-SC9 Drawing #2-1026-P17 Drawing #2-1026-P22F Drawing #2-1026-P8A Drawing #2-1026-P8B Drawing #2-1026-96F Drawing #2-1026-95F Drawing #2-1026-94F Drawing #2-1026-75F Drawing #2-1026-93F Drawing #2-1026-92F Drawing #2-1026-91F Drawing #2-1026-90F	05 Sept. 1975	05 Sept. 1975	Commander, NSEC Code 6164	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
Drawing #2-1026-73F Drawing #2-1026-74F Drawing #2-1026-72F Drawing #2-1026-80F Drawing #2-1026-84F Drawing #2-1026-78F Drawing #2-1026-79F Drawing #2-1026-103F				
.Drawing transmittal Drawing #2-1026-P25F Drawing #2-1026-116F Drawing #2-1026-P23FB Drawing #2-1026-P24F Drawing #2-1026-88F Drawing #2-1026-87F	26 Sept. 1975	26 Sept. 1975	Commander, NSEC Code 6164	
.E003 Contract fund status report	01 Oct. 1975	01 Oct. 1975	Various	See Distribution Schedule
.E002 Milestone cost report	01 Oct. 1975	01 Oct. 1975	Various	See Distribution Schedule
.Public Voucher #II-04	01 Oct. 1975	01 Oct. 1975	Defense Contract Audit Agency	
.Contractors proposal for improved contacts for conveyor.	28 Oct. 1975	28 Oct. 1975	Commander, NSEC Code 6164	
.Contractors proposal to delite MIL-C-2212 from contract because of hi-shock requirement.	28 Oct. 1975	28 Oct. 1975	Commander, NSEC Code 6164	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
.Drawing transmittal	03 Nov. 1975	03 Nov. 1975	Commander, NSEC Code 6164	
Drawing #2-1026-P31F				
Drawing #2-1026-86F				
Drawing #2-1026-114F				
Drawing #2-1026-120F				
Drawing #2-1026-121F				
Drawing #2-1026-122F				
Drawing #2-1026-138F				
Drawing #2-1026-139F				
Drawing #2-1026-142F				
Drawing #2-1026-144F				
Drawing #2-1026-P29F				
Drawing #2-1026-P30F				
Drawing #2-1026-83F				
Drawing #2-1026-85F				
Drawing #2-1026-101F				
Drawing #2-1026-102F				
Drawing #2-1026-105F				
Drawing #2-1026-106F				
Drawing #2-1026-107F				
Drawing #2-1026-108F				
Drawing #2-1026-110F				
Drawing #2-1026-111F				
Drawing #2-1026-113F				
Drawing #2-1026-115F				
Drawing #2-1026-140F				
Drawing #2-1026-141F				
Drawing #2-1026-SC3				
Drawing #2-1026-SC3/J				
Drawing #2-1026-SC2				
Drawing #2-1026-SC7				
Drawing #2-1026-SC1/J				
Drawing #2-1026-143F				

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
Drawing #2-1026-146F Drawing #2-1026-71F Drawing #2-1026-77F Drawing #2-1026-81F Drawing #2-1026-82F Drawing #2-1026-89F Drawing #2-1026-97F Drawing #2-1026-98F Drawing #2-1026-99F Drawing #2-1026-100F Drawing #2-1026-104F Drawing #2-1026-109F Drawing #2-1026-112F Drawing #2-1026-117F Drawing #2-1026-118F Drawing #2-1026-119F Drawing #2-1026-147F Drawing #2-1026-148F Drawing #2-1026-149F Drawing #2-1026-150F				
.Public Voucher #11-05	05 Nov. 1975	05 Nov. 1975	Defense Contract Audit Agency	
.Notification of work stoppage for lack of funds	17 Nov. 1975	17 Nov. 1975	E. J. Wahle, Administrative Officer DCASR-Cinti.	
.Completion of B001AL of CDRL-drawing transmittal. Drawing #2-1026-CC Rev.A Drawing #2-1026-DC Rev.A Drawing #2-1026-SC1 Rev. A Drawing #2-1026-SC9 Rev. B	18 Nov. 1975	18 Nov. 1975	Commander, NSEC Code 6164	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
•Minutes of Design Review Meeting. (Nov. 19 & 20,'75) re. B001AE of the DCRL	25 Nov. 1975	25 Nov. 1975	Commander, NSEC Code 6164	
•Contractor proposal to delete door interlock switches.	25 Nov. 1975	25 Nov. 1975	Commander, NSEC Code 6164	
•Engineering Progress Report CDRL B001AF	21 Jan. 1976	21 Jan. 1976	Commander, NSEC Code 6164	
•Request for Additonal Funds	21 Jan. 1976	21 Jan. 1976	E. J. Wahle, Contract Administrative Officer DCASD--Cinti.	
•Report Transmittal Log	21 Jan. 1976	22 Jan. 1976	Commander, NSEC Code 6164	
•Drawing List 2-1026 DLA Type "A" Conveyor		22 Jan. 1976	Commander, NSEC Code 6164	
•Drawing List 2-1026-DLB Type "B" Conveyor		22 Jan. 1976	Commander, NSEC Code 6164	
•Drawing List 201026 DLC Type "C" Conveyor		22 Jan. 1976	Commander, NSEC Code 6164	
•Return of MOD P00012 Unsigned	13 Feb. 1976	13 Feb. 1976	Dept. of the Navy Code SEA 9244	Out-of-Funds. Unable to establish new data schedule
•Milestone Cost Rept	9 Mar. 1976	9 March 1976	Various	See Distribution Schedule
•Contract Funds Status Report	9 March 1976	9 March 1976	Various	See Distribution Schedule
•Return of MOD P00013 Signed	10 March 1976	10 March 1976	Commander,NSSC Code 0244	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Descript'on	Date of Rept.	Date of Transmittal	To	Remarks
.Transmittal of Failure Modes and Effect Analysis Report	24 Mar. 1976	23 Mar. 1976	Commander, NSEC Code 6164	
.Return of MOD _00014 Signed	6 May 1976	6 May 1976	Commander, NSSC 0244	
.Transmittal of Preliminary copy of the posidyne clutch/ brake trade-off study.	25 June 1976	29 June 1976	Commander, NSEC Code 6164	
.Public Voucher II-06	2 July 1976	2 July 1976	Defense Contract Audit Agency	
.Report of Inventions	16 July 1976	16 July 1976	DCASD, Cinti	
.Transmittal of Final copies of the posidyne clutch/brake trade-off study.	17 July 1976	17 July 1976	Commander, NSEC Code 6164	
.Revised Schedule for Phase II	30 July 1976	30 July 1976	DCASD, Cinti.	
.Transmittal of Minutes of Design Review Meeting held June 21 & 22, 1976	4 Aug. 1976	4 Aug. 1976	Commander, NSEC Code 6164	
..Sketches of Four Alternate Track Designs: 1026-T1 1026-T2 1026-T3 1026-T4	4 Aug. 1976	4 Aug. 1976	Commander, NSEC Code 6164	
.Transmittal of the folbwing data:	14 Oct. 1976	10 Oct. 1976	Commander, NSEC Code 6164	
..Shock Load Calculations. shts. 1 thru 5	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..Impact test results, shts. 1 thru 4	14 Oct. 1976	15 Oct. 1976	Commander, NSEC Code 6164	
..Protective Cover Drawing 2-1026-CL	"	"	"	
..Track Calculations Dwg. 2-1026-SC7 sht. 1 Rev. B	"	"	"	
..Track Calculations Jam Conditions Dwg. 2-1026-SC7 /J sht. 1 of 3	"	"	"	
..Track Calculations Jam Conditions Dwg. 2-1026-SC7 /J sht. 2 of 3	"	"	"	
..Track Calculations Jam Conditions Dwg. 2-1026-SC7 /J sht. 3 of 3	"	"	"	
..Intermediate Track Dwg. 2-1026-315 sht 1 of 1	"	"	"	
..Cam follower clearance Dwg. 2-1026-T5 sht. 1 of 1	"	"	"	
.Contract Funds Status Report	8 Nov. 1976	8 Nov. 1976	Various	See Distribution Schedule
.Milestone Cost Report	8 Nov. 1976	8 Nov. 1976	Various	See Distribution Schedule
.Public Voucher II-07	8 Nov. 1976	8 Nov. 1976	Defense Contract Audit Agency-Columbus	
.Transmittal for Final Calculations for:	10 Nov. 1976	10 Nov. 1976	Commander, NSEC Code 6164	
..Carrier Assy.	"	"	"	
..Carrier Fingers	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..Finger Welds	10 Nov. 1976	10 Nov. 1976	Commander, NSEC Code 6164	
..Fingers with and without gussets	"	"	"	
..Carrier Backbone	"	"	"	
..Carrier Shaft Mounting Bolts	"	"	"	
..Carrier Shaft Welds	"	"	'	
..Carrier Shaft	"	"	"	
..Carrier Shaft Key & Keyway	"	"	"	
..Guide Arm	"	"	"	
..Camrol Mounting Arm	"	"	"	
..Guide Arm Cap	"	"	"	
..Cap Mounting Bolts	"	"	"	
.Transmittal of study on internal bracing.	9 Nov. 1976	9 Nov. 1976	Commander, NSEC Code 6164	
.Transmittal of Drawings	29 Mar. 1977	29 Mar. 1977	Commander, NAVSEC Code 6164	
..2-1026-136F	"	"	"	
..2-1026-137F	"	"	"	
..2-1026-145F	"	"	"	
..2-1026-161F	"	"	"	
..2-1026-165F	"	"	"	
..2-1026-169F	"	"	"	
..2-1026-172F	"	"	"	

Report Transmittal Log

R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..2-1026-174F	29 Mar. 1977	29 Mar. 1977	Commander, NAVSEC Code 6164	
..2-1026-175F	"	"	"	
..2-1026-178F	"	"	"	
..2-1026-182F	"	"	"	
..2-1026-228F	"	"	"	
..2-1026-292F	"	"	"	
..2-1026-293F	"	"	"	
..2-1026-295F	"	"	"	
..2-1026-298F	"	"	"	
..2-1026-300F	"	"	"	
..2-1026-318F	"	"	"	
..2-1026-319F	"	"	"	
..2-1026-320F	"	"	"	
..2-1026-336F	"	"	"	
..2-1026-337F	"	"	"	
..2-1026-74F	"	"	"	
..2-1026-76F	"	"	"	
..2-1026-125F	"	"	"	
..2-1026-126F	"	"	"	
..2-1026-128F	"	"	"	
..2-1026-130F	"	"	"	
..2-1026-132F	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..2-1026-134F	29 Mar. 1977	29 Mar. 1977	Commander, NAVSEC Code 6164	
..2-1026-135F	"	"	"	
..2-1026-153F	"	"	"	
..2-1026-154F	"	"	"	
..2-1026-160F	"	"	"	
..2-1026-170F	"	"	"	
..2-1026-173F	"	"	"	
..2-1026-177F	"	"	"	
..2-1026-183F	"	"	"	
..2-1026-184F	"	"	"	
..2-1026-185F	"	"	"	
..2-1026-289F	"	"	"	
..2-1026-290F	"	"	"	
..2-1026-291F	"	"	"	
..2-1026-296F	"	"	"	
..2-1026-297F	"	"	"	
..2-1026-301F	"	"	"	
..2-1026-302F	"	"	"	
..2-1026-303F	"	"	"	
..2-1026-304F	"	"	"	
..2-1026-305F	"	"	"	
..2-1026-306F	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..2-1026-307F	29 Mar. 1977	29 Mar. 1977	Commander, NAVSEC Code 6164	
..2-1026-308F	"	"	"	
..2-1026-309F	"	"	"	
..2-1026-310F	"	"	"	
..2-1026-311F	"	"	"	
..2-1026-312F	"	"	"	
..2-1026-314F	"	"	"	
..2-1026-323F	"	"	"	
..2-1026-324F	"	"	"	
..2-1026-325F	"	"	"	
..2-1026-326F	"	"	"	
..2-1026-327F	"	"	"	
..2-1026-328F	"	"	"	
..2-1026-331F	"	"	"	
..2-1026-332F	"	"	"	
..2-1026-333F	"	"	"	
..2-1026-338F	"	"	"	
..2-1026-339F	"	"	"	
..2-1026-127F	"	"	"	
..2-1026-267F	"	"	"	
..2-1026-167F	"	"	"	
..2-1026-168F	"	"	"	
..2-1026-171F	"	"		

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept	Date of Transmittal	To	Remarks
..2-1026-176F	29 Mar. 1977	29 Mar. 1977	Commander, NAVSEC Code 6164	
..2-1026-179F	"	"	"	
..2-1026-181F	"	"	"	
..2-1026-322F	"	"	"	
..2-1026-329F	"	"	"	
..2-1026-330F	"	"	"	
..2-1026-P37F	"	"	"	
..2-1026-50F	"	"	"	
..2-1026-124F	"	"	"	
..2-1026-129F	"	"	"	
..2-1026-151F	"	"	"	
..2-1026-152F	"	"	"	
..2-1026-156F	"	"	"	
..2-1025-159F	"	"	"	
..2-1026-166F	"	"	"	
..2-1026-180F	"	"	"	
..2-1026-188F	"	"	"	
..2-1026-133F	"	"	"	
.Letter Transmitting:	29 Mar. 1977	29 Mar. 1977	Commander, NAVSEC Code 0244	
..New Firm Schedule	"	"	"	
..P00016 (Signed)	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
.Transmittal of Drawings:	04 April 1977	04 April 1977	Commander, NAVSEC Code 6164	
..2-1026-P21F-A	"	"	"	
..2-1026-P21F-B	"	"	"	
..2-1026-P21F-C	"	"	"	
..2-1026-71F (Sht. 1)	"	"	"	
..2-1026-71F (Sht. 2)	"	"	"	
..2-1026-71F (Sht. 3)	"	"	"	
..2-1026-157F (Sht. 1)	"	"	"	
..2-1026-157F (Sht. 2)	"	"	"	
..2-1026-158F (Sht. 1)	"	"	"	
..2-1026-158F (Sht. 2)	"	"	"	
..2-1026-159F	"	"	"	
.Transmittal of Drawings:	06 April 1977	06 April 1977	Commander, NAVSEC Code 6164	
..2-1026-P-3A-F	"	"	"	
..2-1026-128F	"	"	"	
..2-1026-162F	"	"	"	
..2-1026-164F	"	"	"	
..2-1026-189F	"	"	"	
..2-1026-190F	"	"	"	
..2-1026-191F	"	"	"	
..2-1026-193F	"	"	"	
..2-1026-197F	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..2-1026-198F	06 April 1977	06 April 1977	Commander, NAVSEC Code 6164	
..2-1026-259F	"	"	"	
..2-1026-260F	"	"	"	
..2-1026-299F	"	"	"	
..2-1026-316F	"	"	"	
..2-1026-317F	"	"	"	
..2-1026-334F	"	"	"	
..2-1026-335F	"	"	"	
..2-1026-340F	"	"	"	
..2-1026-348F	"	"	"	
..2-1026-349F	"	"	"	
..2-1026-350F	"	"	"	
..2-1026-351F	"	"	"	
..2-1026-352F	"	"	"	
..2-1026-353F	"	"	"	
..2-1026-354F	"	"	"	
..2-1026-355F	"	"	"	
..2-1026-356F	"	"	"	
..2-1026-357F	"	"	"	
..2-1026-358F	"	"	"	
..2-1026-359F	"	"	"	
..2-1026-360F	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..2-1026-361F	06 April 1977	06 April 1977	Commander, NAVSEC Code 6164	
..2-1026-362F	"	"	"	
..2-1026-363F	"	"	"	
..2-1026-364F	"	"	"	
..2-1026-365F	"	"	"	
..2-1026-366F	"	"	"	
..2-1026-367F	"	"	"	
..2-1026-368F	"	"	"	
..2-1026-369F	"	"	"	
..2-1026-321F	"	"	"	
..2-1026-200F	"	"	"	
.Transmittal of Drawings:	11 April 1977	11 April 1977	Commander, NAVSEC Code 6164	
..2-1026-272F	"	"	"	
..2-1026-273F	"	"	"	
..2-1026-274F	"	"	"	
..2-1026-276F	"	"	"	
..2-1026-278F	"	"	"	
..2-1026-284F	"	"	"	
..2-1026-286F	"	"	"	
..2-1026-277F	"	"	"	
..2-1026-275F	"	"	"	
..2-1026-279F	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
..2-1026-287F	11 April 1977	11 April 1977	Commander, NAVSEC Code 6164	
..2-1026-270F	"	"	"	
.Transmittal of Drawing:	12 April 1977	12 April 1977	Commander, NAVSEC Code 6164	
..2-1026-347F (Sht. 1)	"	"	"	
..2-1026-347F (Sht. 2)	"	"	"	
.Letter Including:	14 April 1977	14 April 1977	Commander, NAVSEC Code 6164	
..Supplement to Calculations (B001A1)	"	"	"	
..DD250 #KCB0010	"	"	"	
..DD250 #KCB0011	"	"	"	
.Milestone Cost Report	17 April 1977	22 April 1977	Various	See Distribution List
.Contract Funds Status Report	17 April 1977	22 April 1977	Various	See Distribution List
.Public Voucher No. 11-08	22 April 1977	22 April 1977	Defense Contract Audit Agency Columbus, Ohio	
.Letter Including:	05 May 1977	05 May 1977	Commander, NAVSEC Code 6164	
..Response to NAVSEC letter SER 278	"	"	"	
..Transmittal of Drawings	"	"	"	
...2-1026-P26 Rev C	"	"	"	
...2-1026-P20F Rev A	"	"	"	

Report Transmittal Log
R&D Contract #N00024-72-C-5500

Phase II

Description	Date of Rept.	Date of Transmittal	To	Remarks
...2-1026-P27 Rev A	05 May 1977	05 May 1977	Commander, NAVSEC Code 6164	
...2-1026-P47 Rev A	"	"	"	
.Engr. Progress Report CDRL Item B001AF	12 May, 1977	12 May 1977	Commander, NAVSEC Code 6164	
..Report Transmittal Log to 12 May 1977	"	"	"	
..Drawing Transmittal and Useable - on List	"	"	"	
..DD250 #KCB0012	"	"	"	

Section III

Preliminary Engineering Drawing List

A. Conposit List

Shows which drawings apply to each of the three conveyors; shows latest revision letter and date; shows date of transmittal to NAVSEC.

B. Style "A" Conveyor -- 2-1026-DLA Rev B

Shows drawing needed to build and assemble a Style "A" Conveyor-top front loading conveyor.

C. Style "B" Conveyor -- 2-1026-DLB Rev B

Shows drawings needed to build and assemble a Style "B" Conveyor-top rear loading.

D. Style "C" Conveyor -- 2-1026-DLC Rev B

Shows drawings needed to build and assemble a Style "C" Conveyor-recess loading.

Since all the drawings shown on these list have already been transmitted to NAVSEC, and, since all the drawings are subject to further revision until they become approved final drawings during Phase III, the Contractor has elected to save space and cost by not including the preliminary drawings in the report.

CONVEYOR TYPE A (Top Front Loading)	B (Top Rear Loading)	C (Recess Loading)	DRAWING NO. 2-1026	REV.	SHTS.	DRAWING TITLE	REV. DATE	SUB. TO NAVSEC:	PRINT SIZE
X			P21 FA		1	GENERAL ARRANGEMENT		4-4-77	E
	X		P21 FB		1	GENERAL ARRANGEMENT		4-4-77	E
		X	P21 FC		1	GENERAL ARRANGEMENT		4-4-77	E
X	X	X	347F		1 of 2	ELECTRICAL CONTROLS		4-12-77	E
X	X	X			2 of 2	ELECTRICAL CONTROLS		4-12-77	E
X	X	X	P-3-AF		1	CROSS SECTION		4-6-77	E
X			71F		1 of 3	.TRUNK ASSEMBLY		4-4-77	E
X					2 of 3	.TRUNK ASSEMBLY		4-4-77	E
X					3 of 3	.TRUNK ASSEMBLY		4-4-77	E
	X		157F		1 of 2	.TRUNK ASSEMBLY		4-4-77	E
	X				2 of 2	.TRUNK ASSEMBLY		4-4-77	E
		X	158F		1 of 2	.TRUNK ASSEMBLY		4-4-77	E
		X			2 of 2	.TRUNK ASSEMBLY		4-4-77	E
X	X		97F	B	1	..HEAD FRAME	6-7-76	11-3-75	E
		X	159F		1	..HEAD FRAME		4-4-77	E
		X	160F		1	...SPREADER		3-29-77	B
X	X	X	98F	A	1	..INTERMEDIATE FRAME	8-16-76	11-3-75	E
X	X	X	100F	A	1	..LOWER FRAME	8-13-76	11-3-75	E
X	X	X	85F	A	1	...DOUBLE CROSS BAR	8-9-76	11-3-75	C
X	X	X	101F	A	1	...SIDE SHIELD LEFT HAND	7-29-76	11-3-75	C
X	X	X	102F	A	1	...SIDE SHIELD RIGHT HAND	7-30-76	11-3-75	C
X	X	X	114F	A	1	...SHIELD SUPPORT	7-30-76	11-3-75	B
X	X	X	301F		1	...TRACK ANGLE		3-29-77	B
X	X	X	306F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	307F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	308F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	309F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	310F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	311F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	312F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	314F		1	...TRACK LOWER FRAME		3-29-77	B
X	X	X	336F		1	...TRACK TIE PLATE		3-29-77	A
X	X	X	337F		1	...TRACK TIE PLATE		3-29-77	A
X	X	X	338F		1	...JOINT BLOCK		3-29-77	B
X	X	X	339F		1	...SUPPORT BLOCK		3-29-77	B
X	X	X	304F		1	...LEFT HAND CHANNEL SUPPORT		3-29-77	B
X	X	X	305F		1	...RIGHT HAND CHANNEL SUPPORT		3-29-77	B
X	X	X	302F		1	...JOINT BLOCK		3-29-77	B
X	X	X	303F		1	...SUPPORT BLOCK		3-29-77	B
X	X	X	107F	A	1	...SIDE SHIELD, LOWER LEFT HAND	9-16-76	11-3-75	C
X	X	X	108F	A	1	...SIDE SHIELD, LOWER RIGHT HAND	9-16-76	11-3-75	C
X	X	X	106F	A	1	...SINGLE CROSS BAR	7-29-76	11-3-75	C

CONVEYOR TYPE A (Top Front Loading)	B (Top Rear Loading)	C (Recess Loading)	DRAWING NO. 2-1026	REV.	SHTS.	DRAWING TITLE	REV. DATE	SUB. TO NAVSEC	PRINT SIZE
X	X	X	99F	B	1	..TAIL FRAME	8-16-76	11-3-75	E
X	X	X	74F	A	1	...ROD HOLDER	5-6-76	3-29-77	B
X	X	X	147F		1	.LUBRICATION ACCESS HEAD END		11-3-75	E
X	X	X	117F		1	..DOOR FRAME, UPPER		11-3-75	E
X	X	X	118F		1	..DOOR FRAME, INTERMEDIATE SQ. CORNER		11-3-75	E
X	X	X	119F		1	..DOOR FRAME, INTERMEDIATE ROUND CORNER		11-3-75	E
X	X	X	148F		1	..DOOR FRAME, LOWER		11-3-75	E
X	X	X	120F		1	...SIDE PLATE		11-3-75	B
X	X	X	121F		1	...CORNER PLATE		11-3-75	B
X	X	X	122F		1	...SIDE PLATE		11-3-75	B
X	X	X	138F		1	...BOTTOM PLATE		11-3-75	B
X	X	X	139F		1	...TOP PLATE		11-3-75	B
X	X	X	142F		1	...TOP PLATE		11-3-75	B
X	X	X	144F		1	...BOTTOM PLATE		11-3-75	B
X	X	X	104F	A	1 of 3	.SHIELD ASSEMBLY	8-16-76	11-3-75	E
X	X	X		A	2 of 3	.SHIELD ASSEMBLY	8-16-76	11-3-75	E
X	X	X		A	3 of 3	.SHIELD ASSEMBLY	8-16-76	11-3-75	E
X	X	X	77F		1	...INTERMEDIATE REAR SHIELD		11-3-75	E
X	X	X	81F	A	1	..HEAD REAR SHIELD	9-27-76	11-3-75	E
X	X	X	82F	A	1	..HEAD SIDE SHIELD	9-20-76	11-3-75	C
X	X	X	83F	A	1	..FRONT SHIELD EXTENSION	7-29-76	11-3-75	C
X	X	X	89F		1	..FILLER REAR SHIELD		11-3-75	E
X	X	X	105F	A	1	..LOWER FRONT SHIELD	7-29-76	11-3-75	C
X	X	X	109F	A	1	..LOWER REAR SHIELD	8-10-76	11-3-75	E
X	X	X	111F	A	1	..SIDE SHIELD TAIL EXTENSION	7-29-76	11-3-75	C
X	X	X	112F		1	..LOWER REAR SHIELD		11-3-75	E
X	X	X	113F	A	1	..INTERMEDIATE FRONT SHIELD	7-30-76	11-3-75	C
X	X	X	115F	A	1	..FILLER FRONT SHIELD	7-29-76	11-3-75	C
X	X	X	140F	A	1	..INTERMEDIATE FRONT SHIELD	7-29-76	11-3-75	C
X	X	X	146F	A	1	..LOWER FRONT SHIELD	7-29-76	11-3-75	C
X	X	X	316F		1	..ANGLE CLIP		4-6-77	A
X	X	X	317F		1	..CLIP		4-6-77	B
X	X	X	P25 F	B	1	.HEAD UNIT ASSEMBLY	6-7-76	9-26-75	E
X	X	X	P24 F	A	1	..HEAD SHAFT	9-20-76	9-26-75	C
X	X	X	P23 FA	A	1	..HEAD CAM PLATE LEFT HAND	5-14-76	9-26-75	E
X	X	X	P23 FB	A	1	..HEAD CAM PLATE RIGHT HAND	5-13-76	9-26-75	E
X	X	X	87F	A	1	..BEARING HOUSING, HEAD SHAFT	6-7-76	9-26-75	E
X	X	X	88F	A	1	..HEAD CARRIER SPROCKET	5-14-76	9-26-75	C
X	X	X	116F	A	1	..LUBRICATION MOUNTING ASSEMBLY	6-15-76	9-26-75	C
X	X	X	P22 F	A	1	.TAIL UNIT ASSEMBLY	6-10-76	9-5-75	E
X	X	X	P8 A	A	1	..TAIL CAM PLATE, RIGHT HAND	5-17-76	9-5-75	E
X	X	X	P8 B	A	1	..TAIL CAM PLATE, LEFT HAND	6-2-76	9-5-75	E
X	X	X	72 F	A	1	..SPRING RETAINER	5-11-76	9-5-75	A
X	X	X	73 F	A	1	..SPRING SPACER	5-12-76	9-5-75	A

CONVEYOR TYPE Top Front Loading A	Top Rear Loading B	Recess Loading C	DRAWING NO. 2-1026	REV.	SHTS.	DRAWING TITLE	REV. DATE	SUB. TO NAVSEC	PRINT SIZE
X	X	X	75 F	A	1	..BUSHING	5-11-76	9-5-75	A
X	X	X	78 F		1	..ADJUSTING ROD, CAM PLATE		9-5-75	B
X	X	X	90 F	A	1	..TRACK RIGHT FRONT	5-14-76	9-5-75	B
X	X	X	91 F	A	1	..TRACK RIGHT REAR	5-14-76	9-5-75	C
X	X	X	92 F	A	1	..TRACK LEFT FRONT	5-14-76	9-5-75	C
X	X	X	93 F	A	1	..TRACK LEFT REAR	5-11-76	9-5-75	C
X	X	X	94 F	A	1	..BEARING RETAINER	5-11-76	9-5-75	B
X	X	X	95 F	A	1	..TAIL CARRIER SPROCKET	5-14-76	9-5-75	C
X	X	X	96 F	A	1	..END CAP	5-13-76	9-5-75	A
X	X	X	103 F	A	1	..BUSHING	5-13-76	9-5-75	A
X	X	X	318 F		1	..SPRING		3-29-77	A
X	X	X	P20 F	A	1	.CARRIER ASSEMBLY	5-14-76	6-27-75	E
X	X	X	P26	C	1	..CARRIER	2-28-77	6-27-75	D
X	X	X	P27	A	1	..GUIDE ARM	5-10-76	6-27-75	C
X	X	X	P28	C	1	..CARRIER SHAFT	5-10-76	6-27-75	C
X	X	X	41 F	B	1	..CARRIER CHAIN	2-23-77	6-27-75	C
X	X	X	43 F	A	1	..BUSHING	5-13-76	6-27-75	A
X	X	X	48 F	A	1	..CARRIER LINK OUTER ASSEMBLY	5-13-76	6-27-75	B
X	X	X	44 F	A	1	...CARRIER LINK OUTER PLATE	5-13-76	6-27-75	B
X	X	X	46 F	A	1	..CAM FOLLOWER	5-17-76	6-27-75	B
X	X	X	47 F	A	1	..CAP	5-13-76	6-27-75	A
X	X	X	49 F	A	1	..CARRIER LINK INNER ASSEMBLY	5-12-76	6-27-75	B
X	X	X	45 F	A	1	..CARRIER LINK INNER PLATE	5-12-76	6-27-75	B
X	X	X	164 F	A	1	..CAM FOLLOWER	5-12-76	4-6-77	B
X	X	X	162 F	A	1	..CHAIN PIN	2-24-77	4-6-77	A
X	X	X	P10 F	E	1 of 2	.LOADER-UNLOADER ASSEMBLY	5-18-76	7-18-75	E
X	X	X		E	2 of 2	.LOADER-UNLOADER ASSEMBLY	5-18-76	7-18-75	E
X	X	X	150 F	A	1	.LOADER-UNLOADER ASSEMBLY	9-28-76	11-3-75	E
X	X	X	51 F	A	1	..PLATFORM	8-10-76	7-18-75	E
X	X	X	149 F		1	..PLATFORM		11-3-75	E
X	X	X	53 F	A	1	..UNLOADER BRACKET LEFT HAND	5-11-76	7-18-75	C
X	X	X	52 F	A	1	..UNLOADER BRACKET RIGHT HAND	6-25-76	7-18-75	C
X	X	X	55 F	A	1	..CLEVIS ARM	5-11-76	7-18-75	B
X	X	X	56 F	A	1	..CLEVIS	5-11-76	7-18-75	A
X	X	X	57 F	A	1	..CLEVIS PIN	5-11-76	7-18-75	A
X	X	X	58 F	A	1	..SPRING ROD	5-11-76	7-18-75	A
X	X	X	59 F	A	1	..CONNECTING ARM	5-11-76	7-18-75	B
X	X	X	60 F	A	1	..PIVOT BLOCK	5-12-76	7-18-75	B
X	X	X	61 F	A	1	..SHIFTER ARM	5-13-76	7-18-75	C
X	X	X	62 F	A	1	..GUIDE SHAFT	5-6-76	7-18-75	B
X	X	X	63 F	A	1	..GUIDE PLATE	5-6-76	7-18-75	B
X	X	X	64 F	A	1	..PIVOT STUD	5-11-76	7-18-75	A
X	X	X	65 F		1	..SPLIT COUPLING		7-18-75	B

CONVEYOR TYPE A (Top Front Loading)	CONVEYOR TYPE B (Top Rear Loading)	CONVEYOR TYPE C (Recess Loading)	DRAWING NO. 2-1026	DRAWING NO. REV.	SHTS.	DRAWING TITLE	REV. DATE	SUB. TO NAVSEC	PRINT SIZE
X	X	X	76 F		1	..SPRING		3-29-77	B
X	X	X	145 F		1	..SLEEVE BEARING		3-29-77	A
X	X	X	54 F	A	1	..CROSS SHAFT	5-11-76	7-18-75	B
X	X	X	161 F		1	..THRUST BEARING		3-29-77	A
X	X	X	165 F		1	..THRUST BEARING		3-29-77	A
X	X	X	132 F		1	..FLANGED BUSHING		3-29-77	A
X	X	X	300 F		1	..BALL HANDLE		3-29-77	A
X			66 F	A	1	.TOP FRONT LOADER-UNLOADER	5-14-76	7-18-75	E
X			67 F	A	1	..ROLLER ASSEMBLY	5-14-76	7-18-75	C
X			68 F	A	1	..LOAD BAR	5-11-76	7-18-75	B
X			69 F	A	1	..BRACKET	5-11-76	7-18-75	B
X			70 F	A	1	..MOUNTING CLIP	5-11-76	7-18-75	B
	X		151 F		1	.TOP REAR LOADER-UNLOADER ASSEMBLY		3-29-77	E
	X		152 F		1	..TOP REAR LOADER-UNLOADER		3-29-77	E
	X		153 F		1	..MOUNTING BRACKET		3-29-77	B
	X		154 F		1	..LOAD BAR		3-29-77	B
		X	156 F		1	.OVERTRAVEL LIMIT ASSEMBLY		3-29-77	E
X			166 F	A	1	.OVERTRAVEL LIMIT ASSEMBLY	5-12-76	3-29-77	E
	X		180 F	A	1	.OVERTRAVEL LIMIT ASSEMBLY	5-11-76	3-29-77	E
X		X	167 F		1	..PLATFORM		3-29-77	C
	X		181 F		1	..PLATFORM		3-29-77	C
	X		169 F		1	..PLATFORM MOUNTING BRACKET		3-29-77	A
	X		170 F		1	..CONTROL ARM ASSEMBLY		3-29-77	B
	X		171 F		1	..LIMIT SWITCH BRACKET		3-29-77	C
	X		172 F		1	..GUIDE PLATE		3-29-77	A
	X		173 F		1	..DOOR ARM		3-29-77	B
	X		168 F		1	..SPRING BRACKET ASSEMBLY		3-29-77	C
	X		183 F		1	..REACH ARM ASSEMBLY		3-29-77	B
	X		184 F		1	..CONTROL SHAFT		3-29-77	B
	X		185 F		1	..DEFLECTOR		3-29-77	B
			289 F		1	..MOUNTING BRACKET		3-29-77	B
X	X	X	290 F		1	..SPRING ROD		3-29-77	B
X	X	X	291 F		1	..YOKE		3-29-77	B
X	X	X	292 F		1	..PIVOT		3-29-77	A
X	X	X	293 F		1	..CHANNEL		3-29-77	A
X	X	X	295 F		1	..MOUNTING BRACKET		3-29-77	A
X	X	X	296 F		1	..BASE PLATE		3-29-77	B
X	X	X	297 F		1	..MOUNTING PLATE		3-29-77	B
X	X	X	298 F		1	..CONTROL ARM GUIDE PLATE		3-29-77	A
X			319 F		1	..THRUST BEARING		3-29-77	A
X	X	X	320 F		1	..SPRING		3-29-77	A

CONVEYOR TYPE Top Front Loading A	Top Rear Loading B	Recess Loading C	DRAWING NO. 2-1026	REV.	SHTS.	DRAWING TITLE	REV. DATE	SUB. TO NAVSEC	PRINT SIZE
X		X	P37 F		1	.VERTICAL BACK MOUNTED 10 HP. DRIVE		3-29-77	E
X	X	X	200 F		1	.HORIZONTAL RH AND LH SIDE 10 HP. DRIVE		4-6-77	E
X	X	X				...MOTOR		Commercial	
X	X	X				..BRAKE		Commercial	
X	X	X				..REDUCER		Commercial	
X	X	X	124 F		1	..DRIVE BASE		3-29-77	E
X		X	125 F		1	..JACK SHAFT		3-29-77	B
X		X	126 F		1	..COUPLING		3-29-77	B
X		X	127 F		1	..PILLOW BLOCK		3-29-77	C
X		X	128 F		1	..REDUCER DRIVE SPROCKET		4-6-77	B
X		X	188 F		1	..CHAIN GUARD		3-29-77	E
X		X	132 F		1	..TORQUE LIMITER GUARD		3-29-77	B
X		X	133 F		1	..BRAKE ADAPTER PLATE		3-29-77	C
X		X	134 F		1	..HEAD SHAFT SPACER		3-29-77	B
X		X	135 F		1	..HEAD SHAFT END CAP		3-29-77	B
X		X	136 F		1	..JACK SHAFT SPACER		3-29-77	A
X		X	137 F		1	..JACK SHAFT END CAP		3-29-77	A
X		X	334 F		1	..MOTOR SHAFT ADAPTOR		4-6-77	B
X		X	335 F		1	..REDUCER SHAFT ADAPTOR		4-6-77	B
X		X	129 F		1	..HEAD SHAFT DRIVE SPROCKET		3-29-77	E
X		X	323 F		1	...ADJUSTING LUG		3-29-77	B
X		X	324 F		1	...ADJUSTING LUG		3-29-77	B
X		X	325 F		1	...ADJUSTING BRACKET		3-29-77	B
X		X	326 F		1	...HUB		3-29-77	B
X		X	327 F	A	1	...SPROCKET BASE	4-1-77	3-29-77	B
X		X	328 F		1	...WASHER		3-29-77	B
X		X	329 F		1	...SPROCKET		3-29-77	C
X	X	X	321 F		1	..TORQUE LIMITER ASSEMBLY		4-6-77	C
X		X	130 F		1	..CHAIN TAKE-UP		3-29-77	B
X		X	330 F		1	...TAKE-UP BRACKET		3-29-77	C
X		X	331 F		1	...TAKE-UP SLIDE		3-29-77	B
X		X	332 F		1	...IDLER SPROCKET		3-29-77	B
X		X	333 F		1	..PILLOW BLOCK BURN-OUT		3-29-77	B
X	X	X	189 F		1	..DRIVE BASE		4-6-77	E
X	X	X	193 F		1	..ADJUSTING PLATE		4-6-77	C
X	X	X	191 F		1	..JACK SHAFT		4-6-77	C
X	X	X	259 F		1	..JACK SHAFT DRIVE SPROCKET		4-6-77	B
X	X	X	260 F		1	..JACK SHAFT DRIVEN SPROCKET		4-6-77	B
X	X	X	197 F		1	..PILLOW BLOCK		4-6-77	C
X	X	X	348 F		1	..PILLOW BLOCK BURN OUT		4-6-77	C
X	X	X	350 F		1	..JACK SHAFT END CAP		4-6-77	B
X	X	X	351 F		1	..JACK SHAFT SPACER		4-6-77	B

CONVEYOR TYPE			DRAWING NO.		SHTS.	DRAWING TITLE	REV. DATE	SUB. TO NAVSEC	PRINT SIZE
Top Front Loading	Top Rear Loading	Recess Loading							
A	B	C	2-1026	REV.					
X	X	X	352 F		1	..JACK SHAFT SPACER		4-6-77	B
X	X	X	349 F		1	..REDUCER		4-6-77	B
X	X	X	354 F		1	..HEAD SHAFT DRIVE SPROCKET		4-6-77	E
X	X	X	357 F		1	...HUB		4-6-77	B
X	X	X	356 F		1	...SPROCKET BASE		4-6-77	B
X	X	X	355 F		1	...SPROCKET		4-6-77	C
X	X	X	353 F		1	..ADJUSTING SCREW		4-6-77	B
X	X	X	198 F		1	..CHAIN GUARD, UPPER		4-6-77	E
X	X	X	358 F		1	..CHAIN GUARD, LOWER		4-6-77	E
X	X	X	359 F		1	..PILLOW BLOCK SPACER		4-6-77	C
X	X	X	360 F		1	..CHAIN TAKE UP		4-6-77	C
X	X	X	361 F		1	...TAKE-UP BRACKET		4-6-77	C
X	X	X	362 F		1	...TAKE-UP SLIDE		4-6-77	B
X	X	X	363 F		1	...IDLER TAKE-UP SPROCKET		4-6-77	B
X	X	X	340 F		1	..LIMIT SWITCH ASSEMBLY		4-6-77	C
X	X	X	369 F		1	...MOUNTING BRACKET		4-6-77	B
X	X	X	364 F		1	...BRACKET		4-6-77	B
X	X	X	365 F		1	...SWITCH ACTUATOR		4-6-77	A
X	X	X	366 F		1	...MOUNTING PLATE		4-6-77	A
X	X	X	367 F		1	...STUD BOLT		4-6-77	A
X	X	X	368 F		1	...SPACER		4-6-77	A
X	X	X	50 F	A	1	.JAM LIMIT ASSEMBLY	5-20-76	3-29-77	E
X	X	X	174 F		1	..MOUNTING BLOCK		3-29-77	A
X	X	X	175 F		1	..MOUNTING BLOCK		3-29-77	A
X	X	X	176 F		1	..CABLE GUIDE ASSEMBLY		3-29-77	C
X	X	X	177 F		1	..COUNTERWEIGHT		3-29-77	B
X	X	X	178 F		1	..CABLE ASSEMBLY		3-29-77	A
X	X	X	179 F		1	..COUNTERWEIGHT BRACKET ASSEMBLY		3-29-77	C
X	X	X	228 F		1	..CABLE BRACKET		3-29-77	A
X	X	X	141 F		1	..CLEANOUT COVER		11-3-75	C
X	X	X	143 F		1	..PACKAGE GUARD		11-3-75	C
X	X	X	190 F		1	..SERIAL PLATE		4-6-77	B
X	X	X	270 F		1	..LUBE CHART		4-11-77	C
X	X	X	284 F		1	..CONTROL STATION		4-11-77	E
X	X	X	273 F		1	...MOUNTING PLATE		4-11-77	B
X	X	X	274 F		1	...LOCK-OUT COVER		4-11-77	C
X	X	X	286 F		1	...HINGED COVER		4-11-77	C
X	X	X	277 F		1	..MOUNTING CLIP		4-11-77	A
			278 F		1	...LOCK PLATE		4-11-77	B
X	X	X	287 F		1	...INSTRUCTION CHART INTERMEDIATE STATION		4-11-77	C
X	X	X	299 F		1	..WARNING PLATE		4-11-77	B
			272 F		1	...HINGED PLATE		4-11-77	B
X	X	X	275 F		1	...INSTRUCTION CHART MASTER STATION		4-11-77	C
			276 F			...SPACER		4-11-77	A
X	X	X	279 F			...INSTRUCTION CHART MACHINE CONTROL STA.		4-11-77	C

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
B/C	GEN. REVISION	5/20/77	

A. SUPPLEMENTING SHIP EQUIPMENT DRAWING:

EQUIPMENT	MFGR'S. DRAWING NUMBER
VERTICAL STORES HANDLING CONVEYOR	

B. APPLICABLE SPECIFICATION __________

C. NAVY CONTRACT __________

D. MFGR. __________ ORDER NUMBER __________

E. MFGR'S. IDENTIFICATION: SERIAL NO. __________

RATING: __________

DESCRIPTION: __________

F. APPLICATION: SHIPBOARD STORE HANDLING

G. SHIP IDENTIFICATION: __________

H. NO. ITEMS PER SHIP __________ NO. SHIPS INVOLVED __________

I. REFFRENCE DRAWINGS: DRAWING LIST SHEETS 2 THROUGH 13

J. TECHNICAL MANUAL NO. __________

K. COMPONENT IDENTIFICATION NO. __________

L. NOTES:

		KORNYLAK CORPORATION 400 HEATON ST • HAMILTON, OHIO 45011 • 513 863-1277
PREPARED		DRAWING LIST VERTICAL 100 LB. PACKAGE CONVEYOR TRUNK STYLE TOP FRONT LOADING TYPE A
CHECKED		
ENGINEER		

SIZE	CODE IDENT. NO.	DRAWING NO.	REV.
A	07586	2-10[illegible]-DIA	
SCALE		SHEET 1	OF [illegible]

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P21FA		General Arrangement Drawing Top Front Loading Style A	A,B,C,G
	347F (1 of 2)		Electrical Controls	G
	347F (2 of 2)		Electrical Controls	G
	P3-AF		Cross Section	A
	71F (1 of 3)		.Trunk Assembly	A,B
	71F (2 of 3)		.Trunk Assembly	A,B
	71F (3 of 3)		.Trunk Assembly	A,B
	97F	B	..Head Frame	F
	98F	A	..Intermediate Frame	F
	99F	B	..Tail Frame	F
	100F	A	..Lower Frame	F
	101F	A	...Side Shield LH	F
	102F	A	...Side Shield RH	F
	114F	A	...Shield Support	F
	106F	A	...Single Cross Bar	F
	107F	A	...Side Shield LH	F
	108F	A	...Side Shield RH	F
	301F		...Track Angle	F
	306F		...Track Lower Frame	F
	307F		...Track Lower Frame	F
	308F		...Track Lower Frame	F
	309F		...Track Lower Frame	F
	310F		...Track Lower Frame	F
	311F		...Track Lower Frame	F
	85F		...DOUBLE CROSS BAR	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	B

SHEET 2

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	312F		...Track Lower Frame	F
	314F		...Track Lower Frame	F
	336F		...Track Tie Plate	F
	337F		...Track Tie Plate	F
	338F		...Joint Block	F
	339F		...Support Block	F
	304F		...LH Channel Support	F
	305F		...RH Channel Support	F
	302F		...Joint Block	F
	303F		...Support Block	F
	74F	A	...Rod Holder	F
	147F		.Lubrication Access Head End	H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07286	2-1026 DLA	B

SHEET 3

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	104F	A	.Shield Assembly	A,B,G
	83F	A	..Front Shield Ext.	F
	113F	A	..Int. Front Shield	F
	140F	A	..Int. Front Shield	F
	105F	A	..Lower Front Shield	F
	81F	A	..Head Rear Shield	F
	77F		..Int. Rear Shield	F
	89F		..Filler Rear Shield	F
	109F	A	..Lower Rear Shield	F
	112F		..Lower Rear Shield	F
	111F	A	..Side Shield Tail Ext.	F
	146F	A	..Lower Front Shield	F
	82F	A	..Head Side Shield	F
	115F	A	..Filler Front Shield	F
	316F		..Angle Clip	F
	317F		..Clip	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	C

SHEET 4

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	117F		..Door Frame Upper	F
	118F		..Door Frame Inter. Square Corner	F
	119F		..Door Frame Inter. Round Corner	F
	148F		..Door Frame Lower	F
	120F		...Side Plate	F
	121F		...Corner Plate	F
	122F		...Side Plate	F
	138F		...Bottom Plate	F
	139F		...Top Plate	F
	142F		...Top Plate	F
	144F		...Bottom Plate	F
	P25F	B	.Head Unit Assembly	A,B
	P23FA	A	..Head Cam Plate LH	F
	P23FB	A	..Head Cam Plate RH	F
	P24F	A	..Head Shaft	F
	87F	A	..Bearing Housing (Head Shaft)	F
	88F	A	..Carrier Sprocket (Head)	F
	116F	A	..Lubrication Mounting Assembly	H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	B

SHEET 5

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P22F	A	.Tail Unit Assembly	A,B
	P8A	A	..Tail Cam Plate RH	F
	P8B	A	..Tail Cam Plate LH	F
	72F	A	..Spring Retainer	F
	73F	A	..Spring Spacer	F
	75F	A	..Bushing	F
	78F		..Adj. Rod	F
	90F	A	..Track Right Rear	F
	91F	A	..Track Right Rear	F
	92F	A	..Track Lift Front	F
	93F	A	..Track Lift Rear	F
	94F	A	..Bearing Retainer	F
	95F	A	..Tail Sprocket	F
	96F	A	..End Cap	F
	103F	A	..Bushing	F
	318F		..Spring	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	C

SHEET 6

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P20F	A	.Carrier Assembly	A,G,H
	P26	C	..Carrier	F
	P27	A	..Guide Arm	F
	P28	C	..Carrier Shaft	F
	41F	B	..Chain Drawing	F
	162F	A	...Chain Pin	F
	49F	A	..Carrier Link Inner Assembly	F
	45F	A	...Carrier Link Inner	F
	43F	A	...Bushing	F
	46F	A	..Cam Follower	F
	164F	A	..Cam Follower Flanged	F
	47F	A	..Cap	F
	163F	A	..Spacer	F
	48F	A	..Carrier Link - Outer Assembly	F
	44F	A	...Carrier Link - Outer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	B

SHEET 7

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P10F (1 of 2)	E	.Loader Unloader Assembly	A,B
	P10F (2 of 2)		.Loader Unloader Assembly	A,B
	P150F	A	.Loader Unloader Assembly	A,B
	51F	A	..Platform	F
	149F		..Platform	F
	52F	A	..Bracket Assembly RH	F
	182F		...Flanged Bushing	F
	53F	A	..Bracket Assembly LH	F
	182F		...Flanged Bushing	F
	54F	A	..Cross Shaft	F
	55F	A	..Clevis Arm	F
	56F	A	..Clevis	F
	57F	A	..Clevis Pin	F
	58F	A	..Spring Rod	F
	59F	A	..Connecting Arm	F
	60F	A	..Pivot Block	F
	61F	A	..Shifter Arm	F
	62F	A	..Guide Shaft	F
	63F	A	..Guide Plate	F
	64F	A	..Pivot Stud	F
	65F		..Split Coupling	F
	76F		..Spring	F
	145F		..Sleeve Bearing	F
	161F		..Thrust Bearing	F
	165F		..Thrust Bearing	F
	300F		..Ball Handle	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	B

SHEET 8

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	66F	A	.Top Front Loader Unloader	A,B
	69F		..Bracket RH & LH	F
	70F		..Mounting Clip	F
	67F	A	..Roller Assembly	F
	68F	A	..Load Bar	F
	166F	A	.Top Overtravel Limit Assembly	A,B
	167F		..Platform	F
	168F		..Spring Bracket Assembly	F
	289F		...Mounting Bracket	F
	290F		...Spring Rod	F
	291F		...Yoke	F
	292F		...Pivot	F
	293F		...Channel	F
	295F		..Mounting Bracket	F
	170F		..Control Arm	F
	171F		..Limit Switch Bracket	F
	296F		...Base Plate	F
	297F		...Mounting Plate	F
	298F		...Control Arm Guide Plate	F
	172F		..Guide Plate	F
	173F		..Door Arm	F
	320F		..Spring	F
	319F		..Thrust Bearing	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	C

SHEET 9

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	50F	A	.Jam Limit Assembly	A,B
	174F		..Mounting Block Top	F
	175F		..Mounting Block	F
	176F		..Cable Guide Assembly	F
	177F		..Counterweight	F
	178F		..Cable Assembly	F
	228F		...Cable Bracket	F
	179F		..Counterweight Bracket Assembly	F
	P37F		.Vertical Back Mounted 10 HP Drive	G,H
	200F		.Horizontal RH & LH Side 10 HP Drive	G,H
	10 HP FR 286T		..Motor	F
	J80001		..Brake	F
	HU-477970-FM		..Reducer	F
	124F		..Drive Base	F
	125F		..Jack Shaft	F
	126F		..Coupling	F
	127F		..Pillow Block	F
	128F		..Reducer Drive Sprocket	F
	188F		..Chain Guard	F
	132F		..Torque Limiter Guard	F
	133F		..Brake Adapter Plate	F
	134F		..Head Shaft Spacer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	C

SHEET 10

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	135F		..Head Shaft End Cap	F
	136F		..Jack Shaft Spacer	F
	137F		..Jack Shaft End Cap	F
	334F		..Motor Shaft Adaptor	F
	335F		..Reducer Shaft Adaptor	F
	129F		..Head Shaft Drive Sprocket	F
	323F		...Adjusting Lug	F
	324F		...Adjusting Lug	F
	325F		...Adjusting Bracket	F
	326F		...Hub	F
	327F	A	...Sprocket Base	F
	328F		...Washer	F
	329F		...Sprocket	F
	321F		..Torque Limiter Assembly	F
	130F		..Chain Take-Up	F
	330F		...Take-Up Bracket	F
	331F		...Take-Up Slide	F
	332F		...Idler Sprocket	F
	333F		..Pillow Block Burn-Out	F
	189F		..Drive Base	F
	193F		..Adjusting Plate	F
	191F		..Jack Shaft	F
	259F		..Jack Shaft Drive Sprocket	F
	260F		..Jack Shaft Driven Sprocket	F

SIZE	CODE IDENT. NO.	DWG NO.	REV.
A	07586	2-1026DLA	B

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	197F		..Pillow Block	F
	348F		..Pillow Block Burn-Out	F
	350F		..Jack Shaft End Cap	F
	351F		..Jack Shaft Spacer	F
	352F		..Jack Shaft Spacer	F
	349F		..Reducer	F
	354F		..Head Shaft Drive Sprocket	F
	357F		...Hub	F
	356F		...Sprocket Base	F
	355F		...Sprocket	F
	353F		..Adjusting Screw	F
	198F		..Chain Guard, Upper	F
	358F		..Chain Guard, Lower	F
	359F		..Pillow Block Spacer	F
	360F		..Chain Take-Up	F
	361F		...Take-Up Bracket	F
	362F		...Take-Up Slide	F
	363F		...Idler Take-Up Sprocket	F
	340F		..Limit Switch Assembly	F
	369F		...Mounting Bracket	F
	364F		...Bracket	F
	365F		...Switch Actuator	F
	366F		...Mounting Plate	F
	367F		...Stud Bolt	F
	368F		...Spacer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLA	

SHEET : 2

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	141F		..Cleanout Cover	F,G
	143F		..Package Guard	F
	190F		..Serial Plate	D
	270F		..Lube Chart	H
	284F		..Control Station	B,G
	273F		...Mounting Plate	F
	274F		...Lock-Out Cover	F
	286F		...Hinged Cover	F
	277F		..Mounting Clip	F
	278F		...Lock Plate	F
	287F		...Instruction Chart Intermediate Station	D
	299F		..Warning Plate	D
	272F		...Hinged Plate	F
	275F		...Instruction Chart Master Station	D
	276F		...Spacer	F
	279F		...Instruction Chart Machine Control Station	D
	805-1400066		Door Watertight	F,H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLA	

SHEET 13

Form No. 177-8

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
B/C	GEN. REVISION	5/20/77	

A. SUPPLEMENTING SHIP EQUIPMENT DRAWING:

EQUIPMENT	MFGR'S DRAWING NUMBER
VERTICAL STORES HANDLING CONVEYOR	

B. APPLICABLE SPECIFICATION ____________

C. NAVY CONTRACT ____________

D. MFGR. ____________ ORDER NUMBER ____________

E. MFGR'S. IDENTIFICATION: SERIAL NO. ____________

RATING: ____________

DESCRIPTION: ____________

F. APPLICATION: SHIPBOARD STORES HANDLING

G. SHIP IDENTIFICATION: ____________

H. NO. ITEMS PER SHIP ________ NO. SHIPS INVOLVED ________

I. REFERENCE DRAWINGS: DRAWING LIST SHEETS 2 THROUGH 14

J. TECHNICAL MANUAL NO. ____________

K. COMPONENT IDENTIFICATION NO. ____________

L. NOTES:

KORNYLAK CORPORATION
400 HEATON ST • HAMILTON, OHIO 45011 • 513 863-1277

PREPARED			DRAWING LIST VERTICAL 100 LB. PACKAGE CONVEYOR TRUNK STYLE TOP REAR LOADING TYPE B
CHECKED			
ENGINEER			

SIZE	CODE IDENT. NO.	DRAWING NO.	REV.
A	07586	2-1026DLB	B
SCALE		SHEET 1 OF 14	

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P21FB		General Arrangement Drawing Top Rear Loading Style B	A,B,C,G
	347F (1 of 2)		Electrical Controls	G
	347F (2 of 2)		Electrical Controls	G
	P3-AF		Cross Section	A
	157F (1 of 2)		.Trunk Assembly	A,B
	157F (2 of 2)		.Trunk Assembly	A,B
	97F	B	..Head Frame	F
	98F	A	..Intermediate Frame	F
	99F	B	..Tail Frame	F
	100F	A	..Lower Frame	F
	101F	A	...Side Shield LH	F
	102F	A	...Side Shield RH	F
	114F	A	...Shield Support	F
	106F	A	...Single Cross Bar	F
	107F	A	...Side Shield LH	F
	108F	A	...Side Shield RH	F
	301F		...Track Angle	F
	306F		...Track Lower Frame	F
	307F		...Track Lower Frame	F
	308F		...Track Lower Frame	F
	309F		...Track Lower Frame	F
	310F		...Track Lower Frame	F
	311F		...Track Lower Frame	F
	85F		...DOUBLE CROSS BAR	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLB	B

SHEET 2

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	312F		...Track Lower Frame	F
	314F		...Track Lower Frame	F
	336F		...Track Tie Plate	F
	337F		...Track Tie Plate	F
	338F		...Joint Block	F
	339F		...Support Block	F
	304F		...LH Channel Support	F
	305F		...RH Channel Support	F
	302F		...Joint Block	F
	303F		...Support Block	F
	74F	A	...Rod Holder	F
	147F		.Lubrication Access Head End	H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLB	B

SHEET 3

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	104F	A	.Shield Assembly	A,B
	83F		..Front Shield Ext.	F
	113F	A	..Int. Front Shield	F
	140F	A	..Int. Front Shield	F
	105F	A	..Lower Front Shield	F
	81F	A	..Head Rear Shield	F
	77F	A	..Int. Rear Shield	F
	89F		..Filler Rear Shield	F
	109F	A	..Lower Rear Shield	F
	112F		..Lower Rear Shield	F
	111F	A	..Side Shield Tail Ext.	F
	146F	A	..Lower Front Shield	F
	82F	A	..Head Side Shield	F
	115F	A	..Filler Front Shield	F
	316F		..Angle Clip	F
	317F		..Clip	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLB	C

SHEET 4

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	117F		..Door Frame Upper	F
	118F		..Door Frame Inter. Square Corner	F
	119F		..Door Frame Inter. Round Corner	F
	148F		..Door Frame Lower	F
	120F		...Side Plate	F
	121F		...Corner Plate	F
	122F		...Side Plate	F
	138F		...Bottom Plate	F
	139F		...Top Plate	F
	142F		...Top Plate	F
	144F		...Bottom Plate	F
	P25F	B	.Head Unit Assembly	A,B
	P23FA	A	..Head Cam Plate LH	F
	P23FB	A	..Head Cam Plate RH	F
	P24F	A	..Head Shaft	F
	87F	A	..Bearing Housing (Head Shaft)	F
	88F	A	..Carrier Sprocket (Head)	F
	116F	A	..Lubrication Mounting Assembly	H

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P22F	A	.Tail Unit Assembly	A,B
	P8A	A	..Tail Cam Plate RH	F
	P8B	A	..Tail Cam Plate LH	F
	72F	A	..Spring Retainer	F
	73F	A	..Spring Spacer	F
	75F	A	..Bushing	F
	78F		..Adj. Rod	F
	90F	A	..Track Right Rear	F
	91F	A	..Track Right Rear	F
	92F	A	..Track Lift Front	F
	93F	A	..Track Lift Rear	F
	94F	A	..Bearing Retainer	F
	95F	A	..Tail Sprocket	F
	96F	A	..End Cap	F
	103F	A	..Bushing	F
	318F		..Spring	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLB	C

SHEET 6

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P20F	A	.Carrier Assembly	A,G,H
	P26	C	..Carrier	F
	P27	A	..Guide Arm	F
	P28	C	..Carrier Shaft	F
	41F	B	..Chain Drawing	F
	162F	A	...Chain Pin	F
	49F	A	..Carrier Link Inner Assembly	F
	45F	A	...Carrier Link Inner	F
	43F	A	...Bushing	F
	46F	A	..Cam Follower	F
	164F	A	..Cam Follower Flanged	F
	47F	A	..Cap	F
	163F	A	..Spacer	F
	48F	A	..Carrier Link - Outer Assembly	F
	44F	A	...Carrier Link - Outer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLB	B

SHEET 7

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P10F (1 of 2)	E	.Loader Unloader Assembly	F
	P10F (2 of 2)	E	.Loader Unloader Assembly	F
	P150F	A	.Loader Unloader Assembly	F
	51F	A	..Platform	F
	149F		..Platform	F
	52F	A	Bracket Assembly RH	F
	182F		...Flanged Bushing	F
	53F	A	..Bracket Assembly LH	F
	182F		...Flanged Bushing	F
	55F	A	..Clevis Arm	F
	56F	A	..Clevis	F
	57F	A	..Clevis Pin	F
	58F	A	..Spring Rod	F
	59F	A	..Connecting Arm	F
	60F	A	..Pivot Block	F
	61F	A	..Shifter Arm	F
	62F	A	..Guide Shaft	F
	63F	A	..Guide Plate	F
	64F	A	..Pivot Stud	F
	65F		..Split Coupling	F
	76F		..Spring	F
	145F		..Sleeve Bearing	F
	161F	A	..Thrust Bearing	F
	165F		..Thrust Bearing	F
	300F		..Ball Handle	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DL B	B

SHEET 8

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	151F		.Top Rear Loader Unloader Assembly	A,B
	152F		..Top Loader Unloader	F
	153F		..Mounting Bracket	F
	154F		..Load Bar	F
	50F	A	.Jam Limit Assembly	A,B
	174F		..Mounting Block Top	F
	175F		..Mounting Block	F
	176F		..Cable Guide Assembly	F
	177F		..Counterweight	F
	178F		..Cable Assembly	F
	228F		...Cable Bracket	F
	179F		..Counterweight Bracket Assembly	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLB	C

SHEET 9

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	180F	A	.Top Overtravel Limit Assy. Rear Loading	A,B
	181F		..Platform	F
	169F		..Platform Mounting Bracket	F
	183F		..Reach Arm Assembly	F
	168F		..Spring Bracket Assembly	F
	289F		...Mounting Bracket	F
	290F		...Spring Rod	F
	291F		...Yoke	F
	292F		...Pivot	F
	293F		...Channel	F
	295F		..Mounting Bracket	F
	170F		..Control Arm Assembly	F
	171F		..Limit Switch Bracket	F
	296F		...Base Plate	F
	297F		...Mounting Plate	F
	298F		...Control Arm Guide Plate	F
	173F		..Door Arm	F
	172F		..Guide Plate	F
	184F		..Control Shaft	F
	185F		..Deflector	
				F
	320F		..Spring	

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLB	C

SHEET 10

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P37F		.Vertical Back Mounted 10 HP Drive	G,H
	200F		.Horizontal RH & LH Side 10 HP Drive	G,H
	10 HP Fr. 280T		..Motor	F
	J80001		..Brake	F
	HU-477		..Reducer	F
	124F		..Drive Base	F
	125F		..Jack Shaft	F
	126F		..Coupling	F
	127F		..Pillow Block	F
	128F		..Reducer Drive Sprocket	F
	188F		..Chain Guard	F
	132F		..Torque Limiter Guard	F
	133F		..Brake Adapter Plate	F
	134F		..Head Shaft Spacer	F
	135F		..Head Shaft End Cap	F
	136F		..Jack Shaft Spacer	F
	137F		..Jack Shaft End Cap	F
	334F		..Motor Shaft Adaptor	F
	335F		..Reducer Shaft Adaptor	F
	129F		..Head Shaft Drive Sprocket	F
	323F		...Adjusting Lug	F
	324F		...Adjusting Lug	F
	325F		...Adjusting Bracket	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLB	B

SHEET 11

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	326F		...Hub	F
	327F	A	...Sprocket Base	F
	328F		...Washer	F
	329F		...Sprocket	F
	321F		..Torque Limiter Assembly	F
	130F		..Chain Take-Up	F
	330F		...Take-Up Bracket	F
	331F		...Take-Up Slide	F
	332F		...Idler Sprocket	F
	333F		..Pillow Block Burn-Out	F
	189F		..Drive Base	F
	193F		..Adjusting Plate	F
	191F		..Jack Shaft	F
	259F		..Jack Shaft Drive Sprocket	F
	260F		..Jack Shaft Driven Sprocket	F
	197F		..Pillow Block	F
	348F		..Pillow Block Burn-Out	F
	350F		..Jack Shaft End Cap	F
	351F		..Jack Shaft Spacer	F
	352F		..Jack Shaft Spacer	F
	349F		..Reducer	F
	354F		..Head Shaft Drive Sprocket	F
	357F		...Hub	F
	356F		...Sprocket Base	F
	355F		...Sprocket	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLB	

SHEET 12

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	353F		..Adjusting Screw	F
	198F		..Chain Guard, Upper	F
	358F		..Chain Guard, Lower	F
	359F		..Pillow Block Spacer	F
	360F		..Chain Take-Up	F
	361F		...Take-Up Bracket	F
	362F		...Take-Up Slide	F
	363F		...Idler Take-Up Sprocket	F
	340F		..Limit Switch Assembly	F
	369F		...Mounting Bracket	F
	364F		...Bracket	F
	365F		...Switch Actuator	F
	366F		...Mounting Plate	F
	367F		...Stud Bolt	F
	368F		...Spacer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLB	

SHEET 13

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	141F		..Cleanout Cover	F,G
	143F		..Package Guard	F
	190F		..Serial Plate	D
	270F		..Lube Chart	H
	284F		..Control Station	B,G
	273F		..Mounting Plate	F
	274F		...Lock-Out Cover	F
	286F		...Hinged Cover	F
	277F		..Mounting Clip	F
	278F		...Lock Plate	F
	287F		...Instruction Chart Intermediate Station	D
	299F		..Warning Plate	D
	272F		...Hinged Plate	F
	275F		...Instruction Chart Master Station	D
	276F		...Spacer	F
	279F		...Instruction Chart Machine Control Station	D
	805-1400066		.Door Watertight	F,H

SIZE	CODE IDENT. NO	DWG. NO.	REV.
A	07586	2-1026DLB	

SHEET 14

Form No. 177-8

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
B/C	GEN. REVISION	5/20/77	

A. SUPPLEMENTING SHIP EQUIPMENT DRAWING:

EQUIPMENT	MFGR'S DRAWING NUMBER
VERTICAL STORES HANDLING CONVEYOR	

B. APPLICABLE SPECIFICATION ______________________

C. NAVY CONTRACT ______________________

D. MFGR. ______________ ORDER NUMBER ______________

E. MFGR'S. IDENTIFICATION: SERIAL NUMBER ______________

RATING: ______________________

DESCRIPTION: ______________________

F. APPLICATION: SHIPBOARD STORES HANDLING

G. SHIP IDENTIFICATION: ______________

H. NO. ITEMS PER SHIP __________ NO. SHIPS INVOLVED __________

I. REFERENCE DRAWINGS: DRAWING LIST SHEETS 2 THROUGH 13

J. TECHNICAL MANUAL NO. ______________________

K. COMPONENT IDENTIFICATION NO. ______________________

L. NOTES:

KORNYLAK CORPORATION
400 HEATON ST • HAMILTON, OHIO 45011 • 513 863-1277

PREPARED		
CHECKED		
ENGINEER		

DRAWING LIST
VERTICAL 100 LB. PACKAGE CONVEYOR
TRUNK STYLE
TOP RECESSED LOADING TYPE C

SIZE	CODE IDENT. NO.	DRAWING NO.	REV.
A	07586	2-1026DLC	B

SCALE | SHEET 1 OF 13

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	<u>2-1026</u>			
	P21FC		General Arrangement Drawing Top Recessed Loading Style C	A,B,C,G
	347F (1 of 2)		Electrical Controls	G
	347F (2 of 2)		Electrical Controls	G
	P3-AF		Cross Section	A
	158F (1 of 2)		.Trunk Assembly	A,B
	158F (2 of 2)		.Trunk Assembly	A,B
	159F		..Head Frame	F
	160F		...Spreader	F
	98F	A	..Intermediate Frame	F
	99F	[illegible]	..Tail Frame	F
	100F	A	..Lower Frame	F
	101F	A	...Side Shield LH	F
	102F	A	...Side Shield RH	F
	114F	A	...Shield Support	F
	106F	A	...Single Cross Bar	F
	107F	A	...Side Shield LH	F
	108F	A	...Side Shield RH	F
	301F		...Track Angle	F
	306F		...Track Lower Frame	F
	307F		...Track Lower Frame	F
	308F		...Track Lower Frame	F
	309F		...Track Lower Frame	F
	310F		...Track Lower Frame	F
	85F		...Double Cross Bar	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	B

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	311F		...Track Lower Frame	F
	312F		...Track Lower Frame	F
	314F		...Track Lower Frame	F
	336F		...Track Tie Plate	F
	337F		...Track Tie Plate	F
	338F		...Joint Block	F
	339F		...Support Block	F
	304F		...LH Channel Support	F
	305F		...RH Channel Support	F
	302F		...Joint Block	F
	303F		...Support Block	F
	74F	A	...Rod Holder	F
	147F		.Lubrication Access Head End	H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	B

SHEET 3

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	104F (1 of 3)	A	.Shield Assembly	A,B,G
	104F (2 of 3)		.Shield Assembly	A,B,G
	104F (3 of 3)		.Shield Assembly	A,B,G
	83F		..Front Shield Ext.	F
	113F		..Int. Front Shield	F
	140F		..Int. Front Shield	F
	105F		..Lower Front Shield	F
	81F		..Head Rear Shield	F
	77F		..Int. Rear Shield	F
	89F		..Filler Rear Shield	F
	109F		..Lower Rear Shield	F
	112F		..Lower Rear Shield	F
	111F		..Side Shield Tail Ext.	F
	146F		..Lower Front Shield	F
	82F		..Head Side Shield	F
	115F		..Filler Front Shield	F
	316F		..Angle Clip	F
	317F		..Clip	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLC	C

SHEET 4

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	117F		..Door Frame Upper	F
	118F		..Door Frame Inter. Square Corner	F
	119F		..Door Frame Inter. Round Corner	F
	148F		..Door Frame Lower	F
	120F		...Side Plate	F
	121F		...Corner Plate	F
	122F		...Side Plate	F
	138F		...Bottom Plate	F
	139F		...Top Plate	F
	142F		...Top Plate	F
	144F		...Bottom Plate	F
	P25F		.Head Unit Assembly	A,B
	P23FA		..Head Cam Plate LH	F
	P23FB		..Head Cam Plate RH	F
	P24F		..Head Shaft	F
	87F		..Bearing Housing (Head Shaft)	F
	88F		..Carrier Sprocket (Head)	F
	116F		..Lubrication Mounting Assembly	H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLC	B

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P22F		.Tail Unit Assembly	A,B
	P8A		..Tail Cam Plate RH	F
	P8B		..Tail Cam Plate LH	F
	72F		..Spring Retainer	F
	73F		..Spring Spacer	F
	75F		..Bushing	F
	78F		..Adj. Rod	F
	90F		..Track Right Rear	F
	91F		..Track Right Rear	F
	92F		..Track Lift Front	F
	93F		..Track Lift Rear	F
	94F		..Bearing Retainer	F
	95F		..Tail Sprocket	F
	96F		..End Cap	F
	103F		..Bushing	F
	318F		..Spring	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	C

SHEET 6

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P20F	A	.Carrier Assembly	A,G,H
	P26	C	..Carrier	F
	P27	A	..Guide Arm	F
	P28	C	..Carrier Shaft	F
	41F	B	..Chain Drawing	F
	162F	A	...Chain Pin	F
	49F	A	..Carrier Link Inner Assembly	F
	45F	A	...Carrier Link Inner	F
	43F	A	...Bushing	F
	46F	A	..Cam Follower	F
	164F	A	..Cam Follower Flanged	F
	47F	A	..Cap	F
	163F	A	..Spacer	F
	48F	A	..Carrier Link - Outer Assembly	F
	44F	A	...Carrier Link - Outer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	B

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	P10F (1 of 2)	E	.Loader Unloader Assembly	A,B
	P10F (2 of 2)		.Loader Unloader Assembly	A,B
	P150F	A	.Loader Unloader Assembly	A,B
	51F	A	..Platform	F
	149F		..Platform	F
	52F	A	..Bracket Assembly RH	F
	182F		...Flanged Bushing	F
	53F	A	..Bracket Assembly LH	F
	182F		...Flanged Bushing	F
	54F	A	..Cross Shaft	F
	55F	A	..Clevis Arm	F
	56F	A	..Clevis	F
	57F	A	..Clevis Pin	F
	58F	A	..Spring Rod	F
	59F	A	..Connecting Arm	F
	60F	A	..Pivot Block	F
	61F	A	..Shifter Arm	F
	62F	A	..Guide Shaft	F
	63F	A	..Guide Plate	F
	64F	A	..Pivot Stud	F
	65F		..Split Coupling	F
	76F		..Spring	F
	145F		..Sleeve Bearing	F
	161F		..Thrust Bearing	F
	165F		..Thrust Bearing	F
	300F		..Ball Handle	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLC	B

SHEET 8

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	66F	A	.Top Front Loader Unloader	A,B
	69F	A	..Bracket RH & LH	F
	70F	A	..Mounting Clip	F
	67F	A	..Roller Assembly	F
	68F	A	..Load Bar	F
	156F		.Top Overtravel Limit Assembly	A,B
	167F		..Platform	F
	168F		..Spring Bracket Assembly	F
	289F		...Mounting Bracket	F
	290F		...Spring Rod	F
	291F		...Yoke	F
	292F		...Pivot	F
	293F		...Channel	F
	295F		..Mounting Bracket	F
	170F		..Control Arm	F
	171F		..Limit Switch Bracket	F
	296F		...Base Plate	F
	297F		...Mounting Plate	F
	298F		...Control Arm Guide Plate	F
	320F		..Spring	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	C

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	50F	A	.Jam Limit Assembly	A,B
	174F		..Mounting Block Top	F
	175F		..Mounting Block	F
	176F		..Cable Guide Assembly	F
	177F		..Counterweight	F
	178F		..Cable Assembly	F
	228F		...Cable Bracket	F
	179F		..Counterweight Bracket Assembly	
	P37F		.Vertical Back Mounted 10 HP Drive	G,H
	200F		.Horizontal RH & LH Side 10 HP Drive	G,H
	10 HP FR 286T		..Motor	F
	J80001		..Brake	F
	HU-47797C-FM		..Reducer	F
	124F		..Drive Base	F
	125F		..Jack Shaft	F
	126F		..Coupling	F
	127F		..Pillow Block	F
	128F		..Reducer Drive Sprocket	F
	188F		..Chain Guard	F
	132F		..Torque Limiter Guard	F
	133F		..Brake Adapter Plate	F
	134F		..Head Shaft Spacer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	C

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	135F		..Head Shaft End Cap	F
	136F		..Jack Shaft Spacer	F
	137F		..Jack Shaft End Cap	F
	334F		..Motor Shaft Adaptor	F
	335F		..Reducer Shaft Adaptor	F
	129F		..Head Shaft Drive Sprocket	F
	323F		...Adjusting Lug	F
	324F		...Adjusting Lug	F
	325F		...Adjusting Bracket	F
	326F		...Hub	F
	327F	A	...Sprocket Base	F
	328F		...Washer	F
	329F		...Sprocket	F
	321F		..Torque Limiter Assembly	F
	130F		..Chain Take-Up	F
	330F		...Take-Up Bracket	F
	331F		...Take-Up Slide	F
	332F		...Idler Sprocket	F
	333F		..Pillow Block Burn-Out	F
	189F		..Drive Base	F
	193F		..Adjusting Plate	F
	191F		..Jack Shaft	F
	259F		..Jack Shaft Drive Sprocket	F
	260F		..Jack Shaft Driven Sprocket	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	C

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	197F		..Pillow Block	F
	348F		..Pillow Block Burn-Out	F
	350F		..Jack Shaft End Cap	F
	351F		..Jack Shaft Spacer	F
	352F		..Jack Shaft Spacer	F
	349F		..Reducer	F
	354F		..Head Shaft Drive Sprocket	F
	357F		...Hub	F
	356F		...Sprocket Base	F
	355F		...Sprocket	F
	353F		..Adjusting Screw	F
	198F		..Chain Guard, Upper	F
	358F		..Chain Guard, Lower	F
	359F		..Pillow Block Spacer	F
	360F		..Chain Take-Up	F
	361F		...Take-Up Bracket	F
	362F		...Take-Up Slide	F
	363F		...Idler Take-Up Sprocket	F
	340F		..Limit Switch Assembly	F
	369F		...Mounting Bracket	F
	364F		...Bracket	F
	365F		...Switch Actuator	F
	366F		...Mounting Plate	F
	367F		...Stud Bolt	F
	368F		...Spacer	F

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026DLC	

Form No. 177-8

CODE IDENT. NO.	DWG. NO.	REV.	DWG. TITLE	CATEGORY
	2-1026			
	141F		..Cleanout Cover	F,G
	143F		..Package Guard	F
	190F		..Serial Plate	D
	270F		..Lube Chart	H
	284F		..Control Station	B,G
	273F		...Mounting Plate	F
	274F		...Lock-Out Cover	F
	277F		..Mounting Clip	F
	278F		...Lock Plate	F
	287F		...Instruction Chart Intermediate Station	D
	299F		..Warning Plate	D
	272F		...Hinged Plate	F
	275F		...Instruction Chart Master Station	D
	276F		...Spacer	F
	279F		...Instruction Chart Machine Control Station	D
	286F		...HINGED COVER	
	805-1400066		Door Watertight	F,H

SIZE	CODE IDENT. NO.	DWG. NO.	REV.
A	07586	2-1026 DLC	

SHEET 13

Form No. 177-8

Section IV

Reliability and Maintainability Program Plan, Final

A. Reliability Program Plan

The following pages describe the Reliability Program Plan for the high-reliability vertical package conveyor developed for this contract. Goals are: 0.95 criteria for successful system mission; 20,000 hours average life under user conditions; minimuzed redundancy. The Failure Modes and Effects Analysis requred by the Reliability Program Plan has been completed and submitted to Naval Ship Engineering Center on March 23, 1976 (see Item 8 of Section I of this Final Report).

B. Maintainability Program Plan

The pages immediately following the Reliability Program Plan outlined in Section A above, describe the Maintainability Plan for the high-reliability conveyor. Both the Reliability and Maintainability Program Plans were completed and submitted to Naval Ship Engineering Center as a "task element" of Phase II on February 4, 1975 (see Item 1 of Section I of this Final Report).

FINAL

RELIABILITY AND MAINTAINABILITY

PROGRAM PLANS

CDRL ITEM B001AA

USN CONTRACT N00024-72-C-5500

JANUARY 28, 1975

R. A. Larson
General Manager
Systems Logistics

Kornylak Corporation, Hamilton, Ohio

RELIABILITY PROGRAM PLAN
FOR
VERTICAL PACKAGE CONVEYOR

JANUARY 28, 1975

USN CONTRACT N00024-72-C-5500

Kornylak Corporation, Hamilton, Ohio

FOREWORD

The Vertical Package Conveyor Reliability Program Plan describes the reliability work to be accomplished during Phase II - Detailed Design & Development, and Phase III Prototype Build Program, how they will be accomplished, responsibilities, and scheduling. Reference and support information is included in the appendices.

Requirements of MIL-STD-785 and Contract N00024-72-C-5500 are implemented as specified herein to provide for the most economical implementation of work tasks. This program assures that the reliability requirements are determined and satisfied throughout all phases of contract performance. It is planned to substitute MIL-I-45208 Inspection System Requirements in place of MIL-Q-9858 Quality Control Requirement.

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APPENDICES

Section 1

INTRODUCTION

1.1 PURPOSE

The Reliability Program Plan for the Vertical Package Conveyor (VPC) has been prepared and submitted in accordance with the Contract Data Requirements List, Sequence Number B001AA. This document is the master plan for implementing the Kornylak Corporation (KC) reliability program.

1.2 SCOPE

The Reliability Program Plan details the approach, procedures, schedules and management control that KC will use to achieve VPC reliability within requirements of the contract. This plan defines an organized approach to reliability which encompasses the total range of reliability effort from the initial conceptual phase and throughout the design, fabrication, assembly, and test of the VPC. The reliability program is based on the required elements of Contract N00024-72-C-5500 and Military Standard, Reliability Program for Systems and Equipment Development and Production, MIL-STD-785-A.

1.3 OBJECTIVES

A reliability program will be implemented at KC to assure that reliability requirements affecting VPC performance and operating success are identified and satisfied throughout all phases of the VPC contract. Maximum program effectiveness will be provided by interfacing with design personnel during the initial phases of the work and continuing throughout the fabrication and testing phases. Specific actions will be taken and controls instituted to meet reliability program goals as described in this plan.

1.3.1 RELIABILITY PROGRAM GOALS

The system mission or criteria for success is 0.95. Operational success is defined as the probability of successful operation of the VPC during typical ship use conditions. As a design objective KC shall attempt to minimize the occurrence of hardward failures and to prevent failures from occurring by prescribing preventative maintenance routines. In addition, KC shall strive to eliminate or minimize all single failure points.

1.3.2 LIFE

The VPC shall be designed to have an average life of 20,000 hours under user conditions.

1.3.3 DESIGN PHILOSOPHY

The design shall utilize, as far as practical, fully developed and proven parts and components. All equipment shall be designed for worst-case environmental and component tolerance parameters. Operational system success shall be the prime consideration and particular emphasis shall be placed on high availability rate and ease for performing maintenance functions. The mean time between failures (MTBF) will be considered during Phase II Engineering Studies, and Phase III Testing.

1.3.4 REDUNDANCY REQUIREMENTS

Redundancy shall be employed to the lowest practical level consistent with meeting reliability goals. The type redundancy to be utilized shall be selected after a full-failure mode analysis has been performed to determine the possible and most probable failure modes. The application of redundancy techniques shall not be used as justification for poor design practices or the use of equipment of marginal reliability.

Section 2

RELIABILITY PROGRAM MANAGEMENT AND CONTROL

2.1 GENERAL

This section describes the organization, responsibilities, program planning and control, and documentation that will be used to manage and control the reliability program.

In establishing and providing for a realistic and workable program management and control plan, the following was considered.

- Task Responsibility - Each reliability task is identified with an organization responsible for its completion.
- Scheduling - Each task is scheduled.
- Reporting - Program progress and status of accomplishment is reported on a continuing basis.
- Monitoring - The program is monitored and a record kept of all changes so that continuity to the plan is maintained.

2.2 ORGANIZATION

Functional responsibility for the reliability program lies within the Engineering Branch. Work tasks will be performed by personnel skilled in the reliability disciplines and familiar with the activities.

Figure 2-1 shows the responsibilities and tasks assignments by organization. The tasks were abstracted from the work statement requirements.

2.3 PROGRAM PLAN

The Program Plan was prepared in compliance with the VPC Program. This plan constitutes the scope of work of the reliability program.

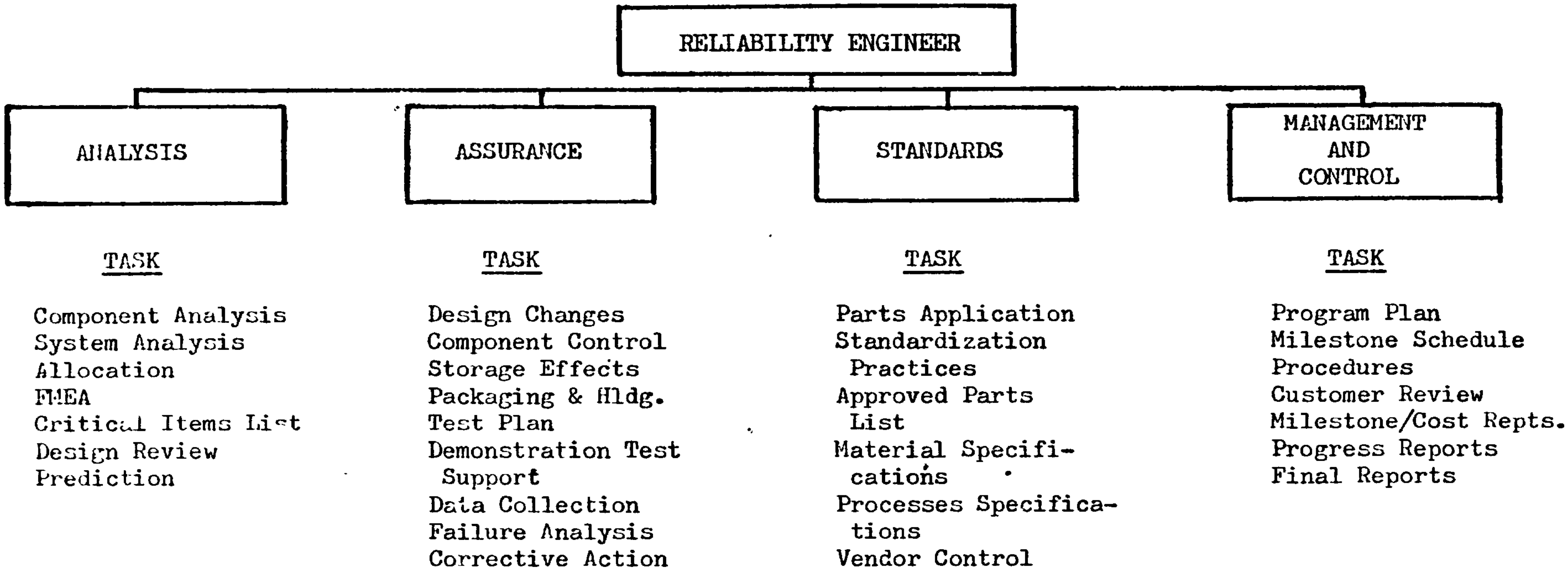


Figure 2-1 Organizational Task Responsibility Chart

2.4 PROGRAM REVISION

Any change in the scope of work will be documented in subsequent revisions and in accordance with General Provisions: Changes, of the contract.

2.5 PROGRAM CONTROL

Program management and control is provided on a continuing basis by supervision and management personnel. This activity is exemplified by adherence to scheduled milestones and status reporting.

2.5.1 PROGRAM SCHEDULE

The functional areas of the reliability program and the schedule of important milestones are identified in Figure 2-2. Milestone dates are in agreement with the overall program plans. Management controls will be maintained in order to meet task milestones in a timely and effective manner.

2.5.2 PROGRAM EVALUATION AND REVIEW

The reliability program of KC is subject to evaluation, review, and inspection by customer designated representatives. Customer - contractor program milestone review points are identified on the schedule of Figure 2-2 for Phase I, II and III.

2.6 DOCUMENTATION

The reliability program is documented by the following reports. Figure 2-3 lists the documents and the contractor Data Requirement List Sequence Number.

2.6.1 PROGRAM PLAN

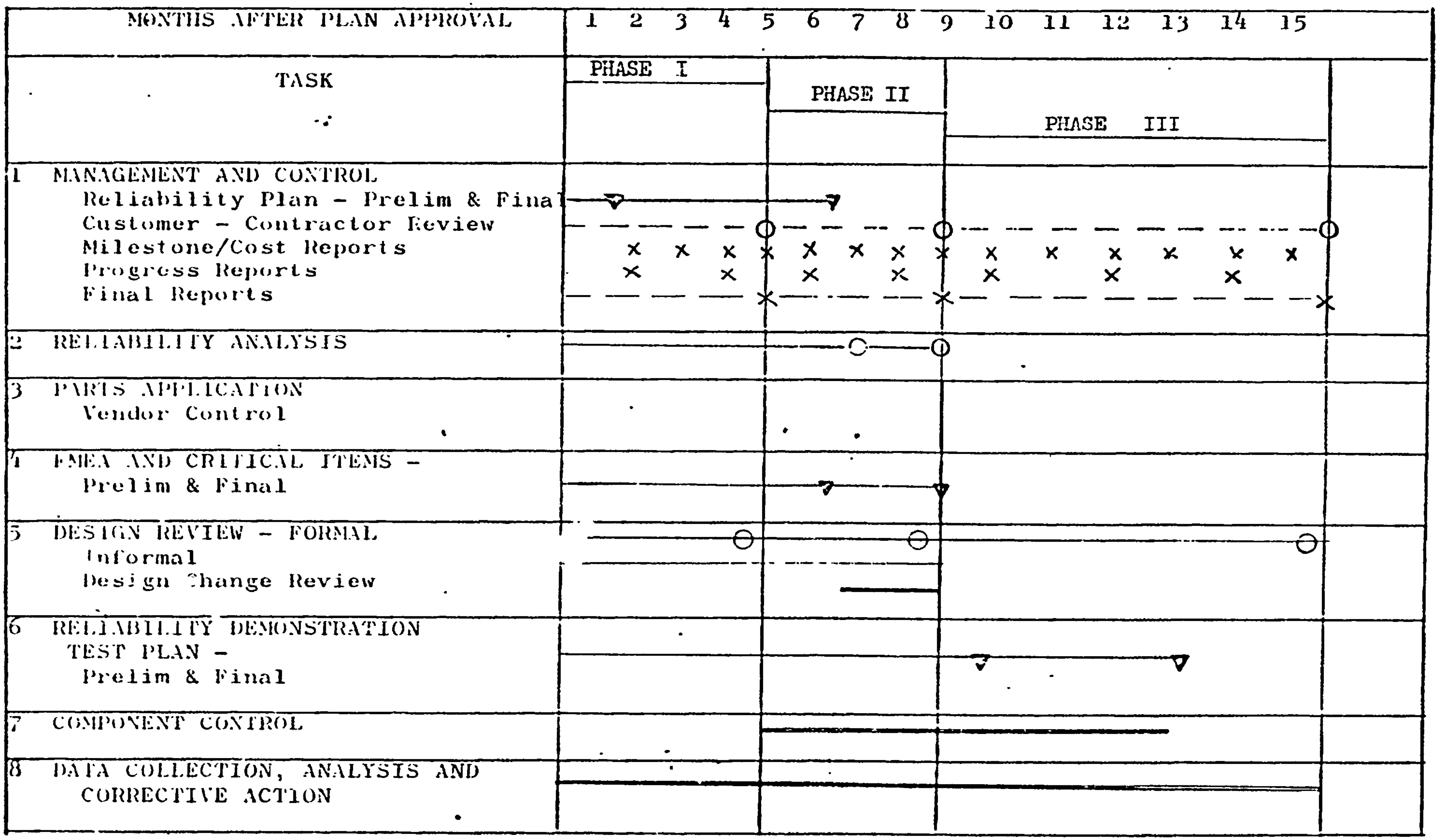
This Preliminary Program Plan is submitted as required by contract. The final Program Plan for Phase II and III will be submitted 45 days after Phase II work commences.

2.6.2 PROGRESS REPORTS

A reliability progress report is submitted as a part of the Progress Report and includes all accomplishments for the preceding quarter.

2.6.3 MILESTONE/COST REPORTS

Inputs will be furnished to the monthly milestone/cost reports.



▼ - Contractual Documentation
O - Scheduled Milestone
X - Support to Documentation Delivery

Figure 2 - 2 Reliability Detail Task Schedule

TITLE	CONTRACTOR DATA REQUIREMENTS LIST	REMARKS
Program Plan	A001AA B001AA	Preliminary Final
Progress Reports	A001AE B001AF C001AM	Input to support documentation delivery
Milestone/Cost Report	E002 (in all phases)	Input to support documentation delivery monthly
Final Report	A001AF B001AG C001AU	Input to support documentation delivery
Design Review Minutes	A001AD B001AE C001AC	15 days after each formal review
FMEA Report	B001AB B001AH	Preliminary Final
Demonstration Test Plan	C001AH C001AK	Preliminary Final

Figure 2-3. Reliability Data Requirements

2.6.4 FINAL REPORT

Inputs to the Final Report will be provided at the completion of Phase I, II and III.

2.6.5 DESIGN REVIEW MINUTES

Minutes of each design review will be prepared and submitted 15 days after each formal design review is completed.

2.6.6 FMEA REPORT

A preliminary and final FMEA Report will be furnished. This report identifies possible modes of failure, effect of the failure on system capability, and the criticality of the failure to system success.

2.6.7 DEMONSTRATION TEST PLAN

A Reliability Demonstration Test Plan will be submitted prior to the scheduled start of testing.

Section 3

TASK PLAN

3.1 GENERAL

Section 3 describes the tasks, their objectives, schedules, and methods of implementation. Figure 2-1 shows the overall reliability program by tasks, grouped in their corresponding categories.

3.2 RELIABILITY ANALYSIS

To satisfy the Reliability Program Goals, Kornylak Corporation will perform reliability analysis on critical components and parts based on the methods described in MIL-STD-785 Military Standard Reliability Program for systems and Equipment Development and Production. The purpose of these analysis is to systematically evaluate key elements of the system to insure that potentially unreliable hardward and critical failure modes are detected and corrected prior to the final design. The analysis will include a review of all critical part and component applications, system redundancy requirements, environmental profiles, and performance tolerances to identify reliability stress levels and opportunities for reliability trade-offs.

The major effort of this will include inputs to the parts application and design review tasks. Work effort continuity will be maintained throughout the program to assess the impact on system reliability which could influence VPC performance. This will be done by updating the reliability analysis as data becomes available from developmental testing and failure analysis results.

3.2.1 ALLOCATION

Reliability objectives will be allocated to the part level based on the methods described in MIL-STD-756A Military Standard Reliability Prediction. Allocated goals on critical hardward will be identified for implementation in specifications, procurement recommendations and design reviews.

3.2.2 PREDICTION

An analysis of all critical parts during Phase II will be performed to determine their probable failure modes and failure rates. This analysis is accomplished in part by preparation of component application sheets which define the component reliability design requirements. All applicable information including specifications, system applications, design characteristics, vendor data and test reports are analyzed and used. This information is prepared for selected components and the results documented.

A continuing review of all test and failure reports is to be maintained and the component reliability analysis is updated as new information becomes available. The results derived from this task will be utilized in making VPC reliability estimates.

A reliability prototype of the VPC will be prepared to show the functional relationships that are necessary for successful VPC operation. A prediction of the reliability for VPC will be made for the hardware configuration of Phase III.

3.3 PARTS APPLICATION

The design of the VPC will utilize proven parts and components as far as practical. Action will be taken during the design reviews to maximize the use of parts and components which have design factors to meet the performance, reliability and quality requirements as specified in the Contract and/or its specification.

Reliability personnel will work closely with the design engineer in order to implement reliability requirements. Feedback of information from previous experience with similar or related designs will be inputed into system development. The design will include application of preferred parts to the greatest extent possible. It shall be an objective during the design review to eliminate from the design parts known to be inadequate.

3.2.2 VENDOR CONTROL

Vendors if required will be chosen that have a proven record of reliability accomplishment. This will be determined based on the ability of the vendor to meet qualification, reliability and maintainability standards for military operations. Vendor surveys will be performed whenever products do not meet specification requirements or whenever functional failures are experienced. Vendor purchase orders for components will contain quantitative requirements for Repair and Maintenance as necessary to satisfy overall contract requirements.

3.4 FAILURE MODE, EFFECT ANALYSIS

A Failure Mode, Effect Analysis (FMEA) shall be performed as an integral part of the design process. This will provide a study of the system to determine possible modes of failure and their effects on system success. A list of critical items will also be furnished.

3.4.1 ANALYSIS REQUIREMENTS

A failure mode effect analysis will be performed to determine modes of system failure and the effect of each failure on operational capability. The FMEA report will be made starting at the system or function level and expanding downward to the part level in order to identify critical functions. Each potential failure will be considered in the light of probability of occurrence and be categorized as to the probable effect on system operating success and personnel safety. The final FMEA will be completed and delivered at the time the design for Phase III is finalized.

3.4.2 APPLICATION

The Reliability Engineer will utilize FMEA data as an input for reliability prediction and safety analysis. An important objective is to discover critical failure areas and to identify means of removing the failure susceptibility from the system. Reliability studies, as described in Section 3.2, will utilize FMEA data to aid the VPC design. Use of the FMEA will also be made to provide an input to the maintainability task and as a major consideration in design reviews.

3.5 DESIGN REVIEW

Engineering design reviews evaluate the design and ability of parts, components, and systems to perform their intended function. Both formal and informal design reviews will be conducted.

3.5.1 FORMAL REVIEW

Formal design reviews will be conducted at which time the designs and drawings will be reviewed and analyzed in detail to determine equipment deficiencies. Improvements to the design and operation will be identified that will increase system reliability, maintainability and safety.

A preliminary design review will be held prior to initial design release. Formal design reviews will be held for the Phase II, III and Phase IV configuration.

The following check lists are used in design review meetings to insure that all potential causes of failures or problems are considered: a) Functional-Mechanical, b) Functional-Electrical, c) Environment, d) Component Requirements, e) System Requirements, f) Reliability, g) Testing, and h) Human Factors/Maintainability Design Review. The Reliability Check List is shown in Appendix I.

3.5.2 INFORMAL CONTINUING REVIEW

Informal continuing reviews in the form of reliability analysis is maintained as a part of the reliability program, as previously described in Section 3.2. This work arrangement assures that the best features for inherently reliable designs are provided to the designers at the earliest possible date. This will help to insure that many reliability principles are incorporated into the design prior to the formal review.

3.5.3 ENGINEERING DESIGN CHANGES

Engineering design changes, after initial release, will be reviewed to determine their effect on system success, availability and safety. As part of the overall change activity, any design change which adds, deletes, or changes the operation of a functional component shall be documented as part of the engineering design change system and consideration given to its effect.

3.6 RELIABILITY DEMONSTRATION

A reliability demonstration test plan will be prepared during Phase III for use in Phase III. This plan will contain information regarding reliability test procedures. Definition of equipment failure, rules for continuation of testing, and failure analysis and corrective action guidelines will be furnished. Reliability demonstration of the VPC will be performed by Kornylak Corporation personnel.

3.7 COMPONENT CONTROLS

Controls will be applied on the VPC in order to provide added confidence that components will perform intended functions. Components whose successful performance is required for operating success, ease of maintenance, and safety will have been identified in the reliability analysis, FMEA, parts application and design review tasks. Continuity will be maintained during hardward manufacture and assembly to assure that reliability and quality is not degraded.

3.7.1 RELIABILITY ASSURANCE

Reliability engineering personnel who participated in the initial phases of the program will also have responsibility to assure that reliability is enhanced. This continuity will provide the basis for evaluation of progress and assurance of reliability. Records will be maintained and reviewed periodically for impact.

All life limited components affected by age or operational characteristics will be identified. Components with special characteristics, safety or reliability requirements will be determined and these requirements will be included in the applicable specification. Components with repetitive quality, test or failure history will be monitored and corrective measures will be implemented to reduce the incidence of recurring problems.

3.8 DATA COLLECTION, ANALYSIS AND CORRECTIVE ACTION

Failure analysis will be performed and corrective action taken on all functional failures. Data will be acquired to insure effective monitoring, information feedback and timely resolution of all problems encountered during the activities under this contract. Failures on critical components shall be assessed for potential impact on the system hardware and operational objectives.

3.8.1 FAILURE DOCUMENTATION

Failures and discrepancies are reported on Incoming Material, Inspection Sheets, Defective Material Notices and Interim Report-Test Problem/ Malfunction. These documents identify and describe problems that occur during incoming inspection, in-plant processing, assembly operations and testing.

3.8.2 FAILURE ANALYSIS AND CORRECTIVE ACTION

All functional failures identified during production, and testing, are closed out by issuing Functional Failure Close-Out Sheets, and Reliability Engineering Test Close Outs. Status of all open functional failures is maintained so that analysis and corrective action and recommendations are made on a timely basis. Corrective action includes design improvements and verification.

APPENDIX I

RELIABILITY CHECK LIST

The following check list is used to ensure that as many potential failure causes as possible are considered.

1) Have corrosion-resistant materials or finishes been provided?

2) Are there dissimilar metals in contact?

3) Are all materials satisfactory for the temperature involved?

4) Is the possibility of flaking considered?

5) Has moisture protection been provided where necessary?

6) Are all materials fungus resistant or inert?

7) Are electrically conductive finishes provided where necessary?

8) Have cantilever mountings been eliminated where possible?

9) Is the trunk and frames sufficiently designed for the application?

10) What are the location and load ratings of mounting points?

11) Where are the heaviest parts located?

12) Have the center of gravity and acceleration been considered in the design.

13) In the case of terminal boards, are the critical components mounted at the edges rather than in the center and are they properly supported?

14) Has clearance been provided with due consideration for vibration, shock and noise stresses?

15) Can electrical instability be caused by vibration of mechanical parts?

16) Are stranded wires properly received close to solder points to prevent flexing?

17) Are proper screw lengths and locking provisions specified?

18) Is the design such that the components may be installed without heat or mechanical damage?

19) Is there adequate accessibility for repair?

20) Does the design eliminate the possibility of inserting the wrong plug or module into a receptacle?

21) Have provisions been made for properly leading cables and wiring around corners and sharp edges?

22) Are grommets provided where needed?

23) Is lacing properly specified and harness well routed and properly clamped?

24) Have cables and connectors been properly identified?

25) Does the system and components have a design life expectancy exceeding all test, checkout, and operational requirements?

26) What is the failure history of the item? Is this a critical item; i.e., would its failure cause system failure?

27) What is the expected or estimated numerical value of reliability of the item?

28) If the item is a newly developed design what are its critical weaknesses? What provision has been made in the design so that modifications can be made at the earliest possible time if these or other weaknesses show up during testing?

APPENDIX II

DEFINITIONS AND ABBREVIATIONS

DEFINITIONS:

COMPONENT	A combination of parts, subassemblies or assemblies, usually self-contained, which performs a distinctive function in the operation of the overall equipment. "A black box."
FAILURE	The inability of a system, subsystem, component, or part to perform its intended function under defined conditions.
FAILURE MODE	The physical description of the manner in which a failure occurs, and the operating conditions of the equipment at the time of failure.
FAILURE RATE	At any point in the life of material, the incremental change in the number of failures per associated incremental changes in the measure of life (cycles, time, miles, event, etc., as applicable).
GENERIC FAILURE RATES	That rate as defined above which would prevail when the part, component, or system is used at rated conditions under ambient laboratory environments.
MAINTAINABILITY	The quality of the combined features of equipment design and installation which facilitates the accomplishment of inspection, test, checkout, servicing, repair, and overhaul with a minimum of time, skill and resources in the planned maintenance environments.
MODEL	A program which uses functional logic expressions together with babilistic values to determine system reliability.
MILESTONE	Any significant event in the design and development of a system or in the associated reliability program which is used as a control point for measurement of progress and effectiveness or for planning or re-directing future effort. Reliability program milestones should be identified in the Reliability Program Plan.
PART	One or more pieces joined together, and which are not normally subject to disassembly without destruction. Generally a constituent of a component.
QUALIFICATION	Determination by a series of tests and examination of documents and processes that a part. component, subsystem, or system is capable of meeting performance requirements prescribed in the specification.

QUALIFICATION DATA	The complete body of data obtained in the qualification testing of a part, component, subsystem or system.
QUALIFICATION TEST	A test or series of tests conducted to determine if a part, component, sybsystem, or system meets qualification requirements.
REDUNDANCY (OF DESIGN)	The use of more than one means of accomplishing a given task or function where all must fail before there is an over-all failure of the system.
RELIABILITY	The probability of a successful operation of the device in the manner and under the conditions of intended customer use.
RELIABILITY TEST	Tests to establish a significant level of engineering confidence in the reliability of the hardware. These tests will be a continuation of qualification tests to verify the life expectancy with the addition of overstress tests as necessary to determine failure modes and safety margins.
SUPPLIER	A contractor, subcontractor or other source producing or providing articles or services required in connection with the prime contract.
SYSTEM	One of the principal functioning entities comprising the project hardware and related operational services within a project or flight mission. Ordinarily, a system is the first major subdivision of project work. Similarily, a subsystem may also be an organized and disciplined approach to accomplish a task, e.g., a failure reporting system.

F I N A L

MAINTAINABILITY PROGRAM PLAN

FOR

VERTICAL PACKAGE CONVEYOR

JANUARY 28, 1975

USN CONTRACT N00024-72-C-5500

Kornylak Corporation, Hamilton, Ohio

FOREWORD

The Vertical Package Conveyor Maintainability Program Plan describes the maintainability work to be accomplished during design development and prototype phases. The plan defines and describes the tasks of the maintainability program, how they will be accomplished, responsibilities; and scheduling.

Requirements of MIL-STD-470, Maintainability Program Requirements and U.S. Navy Contract N00024-72-C-5500 are included in the program plan.

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Section 1

INTRODUCTION

1.1 PURPOSE

The Maintainability Program Plan for the Vertical Package Conveyor (VPC) has been prepared and submitted in accordance with the Contract Data Requirements List, Sequence Number B001AA. This document is the master plan for implementing the Kornylak Corporation (KC) maintainability program.

1.2 SCOPE

The Maintainability Program Plan details the approach, procedures, schedules and management control that KC will use to achieve VPC maintainability within the requirements of the contract. This plan defines an organized approach to maintainability which encompasses the total range of effort from the initial conceptual phase and throughout the design, fabrication, assembly, test, and delivery of the VPC. The program is based on the required elements of Contract N00024-72-C-5500 and Military Standard, Maintainability Program Requirements MIL-STD-470.

1.3 OBJECTIVES

A maintainability program will be implemented at Kornylak to assure that requirements affecting VPC performance and operating success are identified and satisfied throughout the VPC contract. Maximum program effectiveness will be provided by interfacing with design personnel during the initial phases of the work and continuing throughout the fabrication and testing phases. Specific actions will be taken and controls instituted to meet program goals as described in this plan.

1.3.1 MAINTAINABILITY PROGRAM GOALS

The goal for mean time to repair is: No more than 1 of 20 simulated preventative maintenance (P.M.) tasks shall exceed 2 hours, and no P.M. tasks shall exceed 4 hours. No more than 2 of 20 corrective maintenance tasks shall exceed 5 hours and the mean time to repair shall not exceed 3 hours.

1.3.2 MAINTAINABILITY PHILOSOPHY

The maintainability philosophy will be to utilize to the maximum extent possible those design practices which allow for ease and speed of both preventative and corrective maintenance. Requirements for special tools or test equipment will be held to a minimum. Tasks requiring special skills will be reviewed to determine that no practical alternative exists.

Section 2

MAINTAINABILITY PROGRAM MANAGEMENT AND CONTROL

2.1 GENERAL

This section describes the organization, responsibilities, program planning and control, and documentation that will be used to manage and control the program.

In establishing and providing for a realistic and workable program management and control plan, the following was considered.

Task Responsibility. Each task is identified with an organization responsible for its completion.

Scheduling. Each task is scheduled.

Reporting. Program progress and status of accomplishment is reported on a continuing basis.

Monitoring. The program is monitored and a record kept of all changes so that continuity is maintained.

2.2 ORGANIZATION

Functional responsibility for the maintainability program lies within the Engineering Branch. Work tasks will be performed by personnel skilled in the disciplines and familiar with the activities required.

Figure 2-1 shows the responsibilities and task assignments by component organization. The tasks were abstracted from the work statement requirements.

2.3 PROGRAM PLAN

The Program Plan was prepared in compliance with the VPC Program requirements. This plan constitutes the scope of work of the maintainability program.

2.4 PROGRAM REVISION

Any change in the scope of work will be documented in subsequent revisions of the program plan.

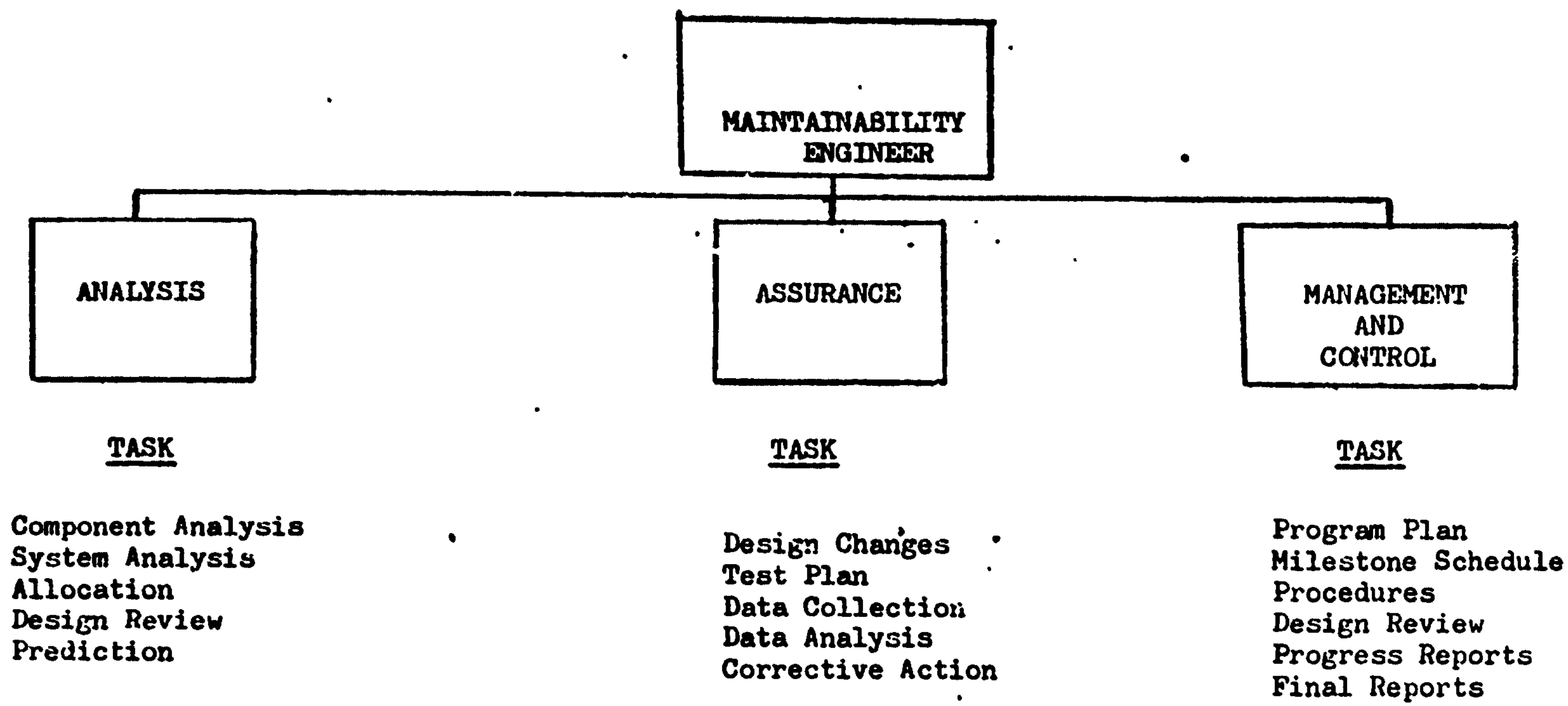


Figure 2-1 Organizational Task Reponsibility Chart

2.5 PROGRAM CONTROL

Program management and control is provided on a continuing basis by supervision and management personnel. This activity is exemplified by adherence to scheduled milestones, and status reporting.

2.5.1 PROGRAM SCHEDULE

The functional areas of the program and the schedule of important milestones are identified in Figure 2-2. Milestone dates are in agreement with the overall program plans. Management controls will be maintained in order to meet task milestones in a timely and effective manner.

2.6 DOCUMENTATION

The program is documented by the following reports. Figure 2-3 lists the documents and the contractor Data Requirement List Sequence Number.

2.6.1 PROGRAM PLAN

This Preliminary Program Plan is submitted as required by contract. The final Program Plan for Phase II and III will be submitted 45 days after Phase II work commences.

2.6.2 PROGRESS REPORTS

A maintainability progress report is submitted as a part of the Progress Report and includes all accomplishments for the preceding quarter.

2.6.3 FINAL REPORT

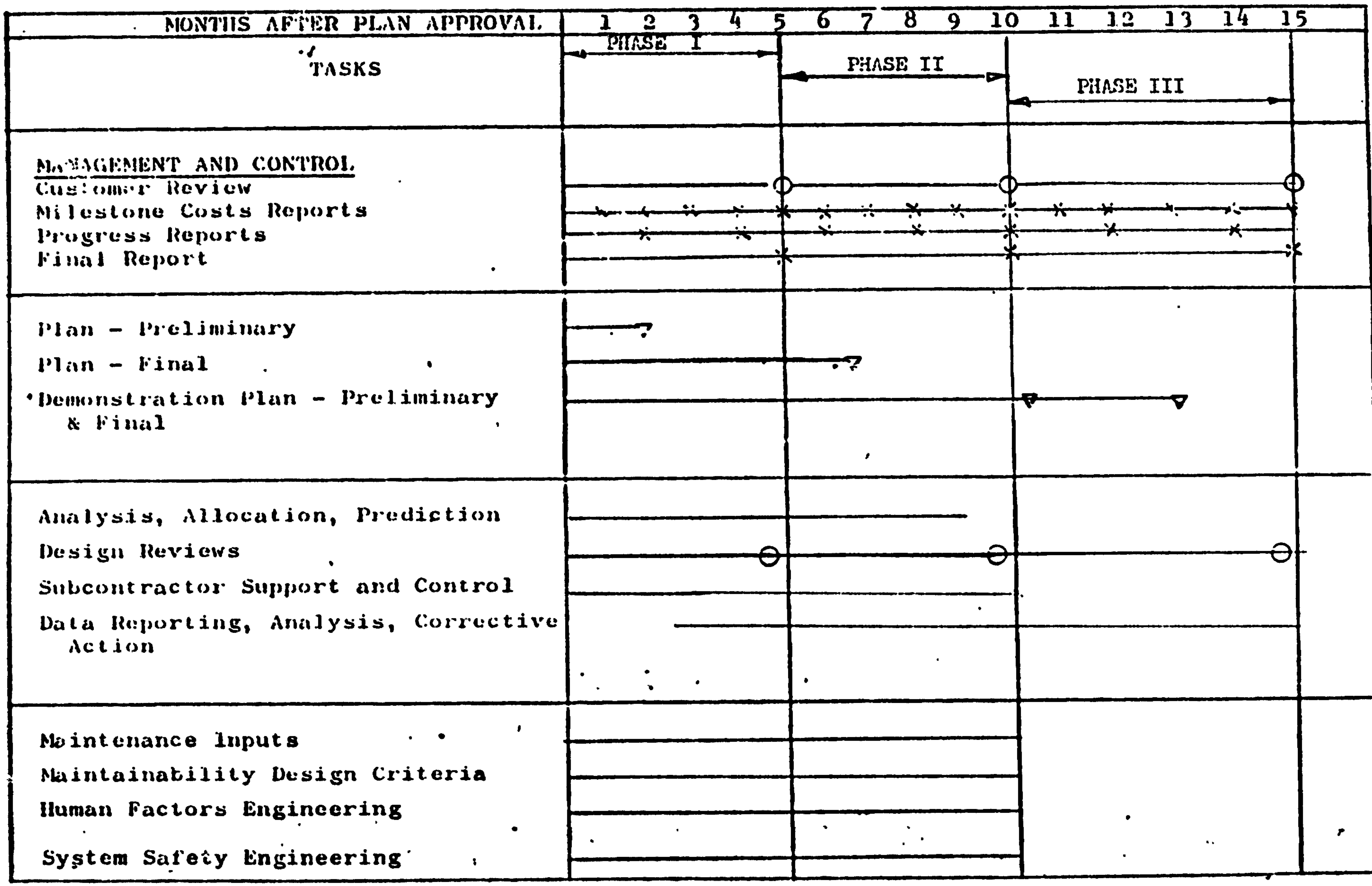
Inputs to the Final Report will be provided at the completion of Phase III.

2.6.4 DEMONSTRATION TEST PLAN

A Maintainability Demonstration Test Plan will be submitted prior to the scheduled start of testing.

2.7 RELATION TO INTEGRATED LOGISTICS PLAN

The integrated logistics plan must consider: 1) the maintainability plans provision for periodic maintenance, 2) spares provisioning necessary to meet the MTBF for specific equipments, and 3) equipment utilization to meet the availability requirements. When the maintainability requirements are established, the logistics plan should be amended to assure adequate spares to meet the requirements of the overall system.



▼ - Contractual Documentation Delivery   X - Support to Documentation Delivery

O - Scheduled Milestones

Figure 2-2 Maintainability Schedule

2.8 LIAISON BETWEEN MAINTAINABILITY AND RELIABILITY

There will be constant interchange of collected data between the maintainability and the reliability functions.

2.9 PROGRAM REVIEWS

Informal design reviews will be made on a continuing basis as the system/equipment design evolves. To assure the incorporation of maintainability requirements, these informal reviews will includ a current comparison of maintenance time predictions with downtime apportionments. The design guidelines will be used as guides in evaluating designs for qualitative maintainability features.

PDR's will be conducted during the design phase of the program to maintain close liaison with program personnel and to provide assistance in:

a. Evaluating the relative maintainability merit of system configuration being considered.

b. Evaluating the effect of proposed design changes on system maintainability.

2.10 SUBCONTRACTOR RELATIONS

Subcontractors will be required as necessary to provide maintainability plans and/or maintainability data. Currently, no equipment subcontractors are contemplated. However, in the event that a subcontractor is chosen to design and produce a portion of the system, the requirements of this paragraph and MIL-STD-470 will be imposed.

TITLE	CONTRACTOR DATA REQUIREMENTS LIST	REMARKS
Program Plan	A001AA B001AB	Preliminary Final
Progress Reports	A001AE	Input to support documentation delivery quarterly
Final Report	A001AF B001AG C001AU	Input to support documentation delivery
Demonstration Test Plan	C001AG C001AJ	Preliminary Final

Figure 2-3. Maintainability Data Requirements

Section 3

TASK PLAN

3.1 GENERAL

Section 3 describes the tasks, their objectives, schedules, and methods of implementation. Figure 2-1 shows the overall maintainability program by tasks grouped in their corresponding categories.

3.2 MAINTAINABILITY ANALYSIS

In order to satisfy program goals, Kornylak Corporation will perform analysis on critical components and parts during basic research and development, to influence the design of the VPC. The maintainability analysis of the system shall identify the maintainability characteristics of the equipment and components of the system in terms of their contribution to the overall system maintainability. Factors considered shall include, but not be limited to, mean time between failure, mean time to repair, mean time for scheduled maintenance, operational requirements, skills, special equipment, levels and location of facilities, and mean down time.

The output of the maintainability analysis will be the quantitative and qualitative maintainability requirement, with a maintenance concept and maintenance plan.

3.2.1 MAINTAINABILITY ALLOCATION

As an aid to design and to achieve required maintainability goals, allocation of maintainability parameters will be developed early in the program. The allocation will be made by assigning corrective downtime goals to part levels based on failure rates and preventive maintenance requirements. Item with the highest frequency of failure or servicing will be assigned maintenance time allocations sufficiently low that the required downtime criteria can be met.

3.2.2 MAINTAINABILITY PREDICTION

The contractor will provide predictions of maintainability parameter values for the system. The prediction technique used will be as defined in MIL-HDBK-72. The prediction technique will estimate the quantitative maintainability system parameter values for the planned design configuration. The quantitative estimates will be used to judge the adequacy of the proposed design to meet the maintainability predicted requirements and identify design features requiring corrective action.

3.3 MAINTAINABILITY DEMONSTRATION

Maintainability Demonstration will be accomplished by the Kornylak Corporation in accordance with the Maintainability Demonstration Plan. This plan will be developed in accordance with MIL-STD-471, Military Standard Maintainability Demonstration.

3.4 HUMAN FACTORS ENGINEERING

The human factors engineering will support the maintainability activity. Principles and procedures of Human Factors Engineering will be applied to decisions during the development, manufacturing, testing and operation of the system. MIL-STD-1472 and MIL-H-46855 will be the basic reference documents. The approval of drawings by Engineering will verify that the configuration and arrangement of equipment satisfy man/equipment performance requirements.

3.5 MAINTAINABILITY ASSURANCE

The contractor will establish and periodically up-date detailed maintainability criteria determined from the repetitive system analysis. Appropriate consideration of maintainability criteria will be reflected in design concept reviews, item selection, design reviews and trade-offs.

3.6 MAINTENANCE CONCEPT AND PLAN

One output of the maintainability analysis is the maintenance concept for the Vertical Package Conveyor. Areas to be covered in the maintenance concept include preventive maintenance such as lubrication of reducers, inspection and test requirements such as checking the torque limiting device setting, corrective maintenance concepts such as the replacement of relays and periodic overhaul requirements such as replacement of bearings.

The maintainability analysis will develop the preliminary maintenance plan specifying levels and types of maintenance required.

3.7 MAINTAINABILITY REPORTING

Maintainability and Human Factors data will be collected on the data form shown as Figure 3-1. This form will be initiated by the test engineer/technician when failures or unsatisfactory conditions occur. Copies of these reports will be used for Kornylak Corporation Maintainability analysis.

MAINTAINABILITY/HUMAN FACTORS FAILURE REPORT

Contract Number ______________ Form Number ______________

1. Date of Failure ______________________________

2. Elapsed Time at Time of Failure ______________ hours

   Elapsed Cycles at Time of Failure ______________ cycles

3. Failed Piece Part of Item (Name and Identification) ______________

   Primary ______________________________

   Secondary ______________________________

4. Cause of Failure (Design, Workmanship, Human, Unknown, Wear-Out, Other; Explain)

____

____

____

4a. No. of previous failures of same part in testing period ______________

5. First Indication of Malfunction (Did Anyone Observe the Failure?)

____

____

6. Mode of Operation When Failure Occurred ______________

____

7. Effect of Failure on Part ______________

____

8. Effect of Failure on System ______________

____

9. Detailed Failure Analysis ______________

____

10. Repair Action (or Action Taken to Correct Deficiency)--(e.g. Correct, Replace, Eliminate, Modify, Design, Modify Part, Other; Describe Concisely the Action Taken)

____

____

11. Describe any change in maintenance requirements as result of repair action ______

____

____

11. Verification Action Planned to Check Adequacy of Corrective Action ______________

____

12. Cost of Repair Parts (or Remedy) ____

____

13. Skill Level Required to Repair Failed Item ____________________________________

____

14. Diagnostic Time to Isolate Trouble ____________ hours ____________ min.

* Actual Time to Repair ____________ hours ____________ min.

Man-Hours to Repair ____________ hours ____________ min.

**Down Time ____________ hours ____________ min.

15. Scheduled (Preventive) Maintenance Associated with Failed Part

____

16. Name of Reporter ____

* Actual Time to Repair is the length of time spent in determining the problem and repairing the machine.

**Down Time is the length of time that the unit is not operational. It includes such times as time away from repair due to meals, holidays, waiting for ordered parts and administrative delays.

Figure 3-1. Maintainability/Human Factors Failure Reporting Form

Maintainability analysis of the reports will be performed and the results of the analysis will be provided to design the Maintainability Plan and prepare the Maintenance Engineering Technical Manuals. Follow-up will be maintained and status reported in the progress reports.

Section V

Failure Modes and Effects Analysis

A. FMEA Selection and Criteria Report

The following FMEA Selection and Criteria Report was prepared and submitted to Naval Ship Engineering Center April 14, 1975 (see Item 2 of Section I of this Final Report).

B. Failure Modes and Effects Analysis

The pages immediately following the FMEA Selection and Criteria Report comprize the Failure Modes and Effects Analysis completed and submitted by the Contractor to Naval Ship Engineering Center on March 23, 1976 (see Item 8 of Section I of this Final Report).

FMEA Selection and Criteria Report
DD 1423 Item B001AB

(partial fulfillment of line item 004
re Contract No. N00024-72-C-5300)

Copies: 6

Reproducibles: 0

Submitted: Commander, Naval Ship
Engineering Center
Center Bldg. Prince Georg. Center
Hyattsville, Md. 20782
Code 6164

Attention: Mr. Satterthwaite
cc: Mr. Otto

Note: Original enclosed copy of DD 250 should be signed at destination and distribution made including a signed copy to:

Kornylak Corporation

400 Heaton Street
Hamilton, Ohio 45011
Attention: Mr. R.A. Larson

Submittal date: 10 April 1975

F M E A

Selection and Criteria Report
CDRL Item B001AB
USN Contract N00024-72-C-5500
April 10, 1975

R. A. Larson, General Manager

Kornylak Corporation
Hamilton, Ohio

FAILURE MODES AND EFFECTS ANALYSIS
SELECTION AND CRITERIA REPORT

1. SCOPE

1.1 The Failure Modes and Effects Analysis (FMEA) Selection and Criteria Report contains:

(a) A narrative functional description of the vertical stores conveyor.

(b) A functional block diagram.

(c) An indentured block diagram detailed down to the indentured level which will identify replaceable parts or components.

(d) A list of the items recommended for FMEA application.

(e) An outline of the depth to which FMEA will be applied within each assembly and subassembly.

(f) A description of the type of failure modes associated with each item selected for FMEA application.

(g) A description of the criteria to be used for identifying critical items (MIL-STD-1629 (Ships) will be used as applicable).

(h) The rational for selecting the items and associated failure modes for FMEA.

2. APPLICABLE DOCUMENTS

2.1 To the extent applicable the following documents will be used to prepare and support this report:

Standards:

MIL-STD-470 -- Maintainability Program Requirements (for Systems and Equipment)

MIL-STD-785 -- Reliability Program for Systems and Equipment Development and Production

MIL-STD-1629 (Ships) -- Procedures for Performing a Failure Mode and Effect Analysis for Shipboard Equipment

Reports:

"Reliability and Maintainability Program Plans - Final" (prepared by Kornylak Corporation and submitted January 28, 1975 under CDRL Item B001AA of USN Contract #N00024-72-C-5500).

"Reliability Studies Including Corrective Action Plan for Vertical Package Conveyor"(prepared by Kornylak Corporation and submitted August 10, 1972 under CDRL Item A001AG-1 of USN Contract #N00024-72-C-5500.

3. EQUIPMENT DESCRIPTION AND FUNCTIONAL BLOCK DIAGRAM

3.1 Narrative functional description. The vertical stores conveyor is used to convey goods and stores from one ship's level to another. The conveyor is equipped with vertically moving trays to carry packages weighing up to 100 pounds in sizes up to 36 inches wide by 24 inches deep by 36 inches high. Each load station is equipped with platforms that can be positioned to mechanically eject packages at that load station; these devices can also be positioned as a load platform to position loads for pick-up during strike-up operation. Speed of operation can be selected at 8, 12 and 16 trays per minute. The machine is electrically motor-driven through a non-overhauling reducer. An electrical brake is used to stop conveyor motion. The conveyor is controlled thru a series of push-button stations located at each load station. One of these stations is designated the "master control station" and has the additional function of turning power "on" and selecting conveyor speed. Safety devices are incorporated to protect the motor against overload and to sense incipient package jams stopping the conveyor. An audio signal warns the operator that the conveyor is about to start.

3.2 Functional block diagram. The following block diagram and block diagram sub-systems provide the structural data for the FMEA.

Number 100	-	Vertical conveyor system
Number 10	-	Drive system
Number 20	-	Structure
Number 30	-	Operating system
Number 40	-	Control system
Number 50	-	Safety devices
Number 60	-	Load/unload devices

The functional interrelationships between these devices and sub-systems is shown on Figure No. 1.

3.2.1 Sub-System number-10 - Drive system

The drive system powers the conveyor thru a chain and sprocket system. The drive sprocket and chain are considered part of the drive system. The rest of the system consists of:

Number 10.1	-	Base plate
Number 10.2	-	Motor
Number 10.3	-	Torque limiter
Number 10.4	-	Reducer
Number 10.5	-	Brake
Number 10.6	-	Jack shaft coupling

Number 10.7 - Jack Shaft

Number 10.8 - Pillow block bearing

Number 10.9 - Drive sprockets & keys

Number 10.10 - Drive chain

Number 10.11 - Drive chain take-up

The drive system may be back, left side or right side mounted - as selected by the procuring activity. The functional interrelationship between the components of the drive system is shown on Figure No. 2.

3.2.2 Sub-System number 20 - Structure

The structure consists of the conveyor trunk or frame, door frames and doors, and various internal shields. The trunk or frame is the basic supporting and mounting structure for the drive system and all operating elements. The door frame is fastened to the trunk (not the frame of frame types) and supports the door hinging and "dogging" mechanism. A variety of shields are included as "structure" although they do not contribute to conveyor support. These shields guard the package area and the operating mechanism. The structure consists of:

Number 20.1 - Trunk (or frame)

Number 20.2 - Door framing

Number 20.3 - Shields

3.2.2.1 The main structure or trunk of the conveyor is sized to adequately support the drive system, operating system, shields, door frames and operating loads. The trunk is also sized to withstand whatever water pressure head is specified by the procuring activity. The trunk is permanently welded to the ship's deck and becomes a part of the ship's structure. The trunk consists of welded plates forming a rectangular box of a length necessary to service the deck levels specified. The shields are formed sheet steel bolted or welded to the trunk by suitable supports and/or bracketry. Door frames are welded

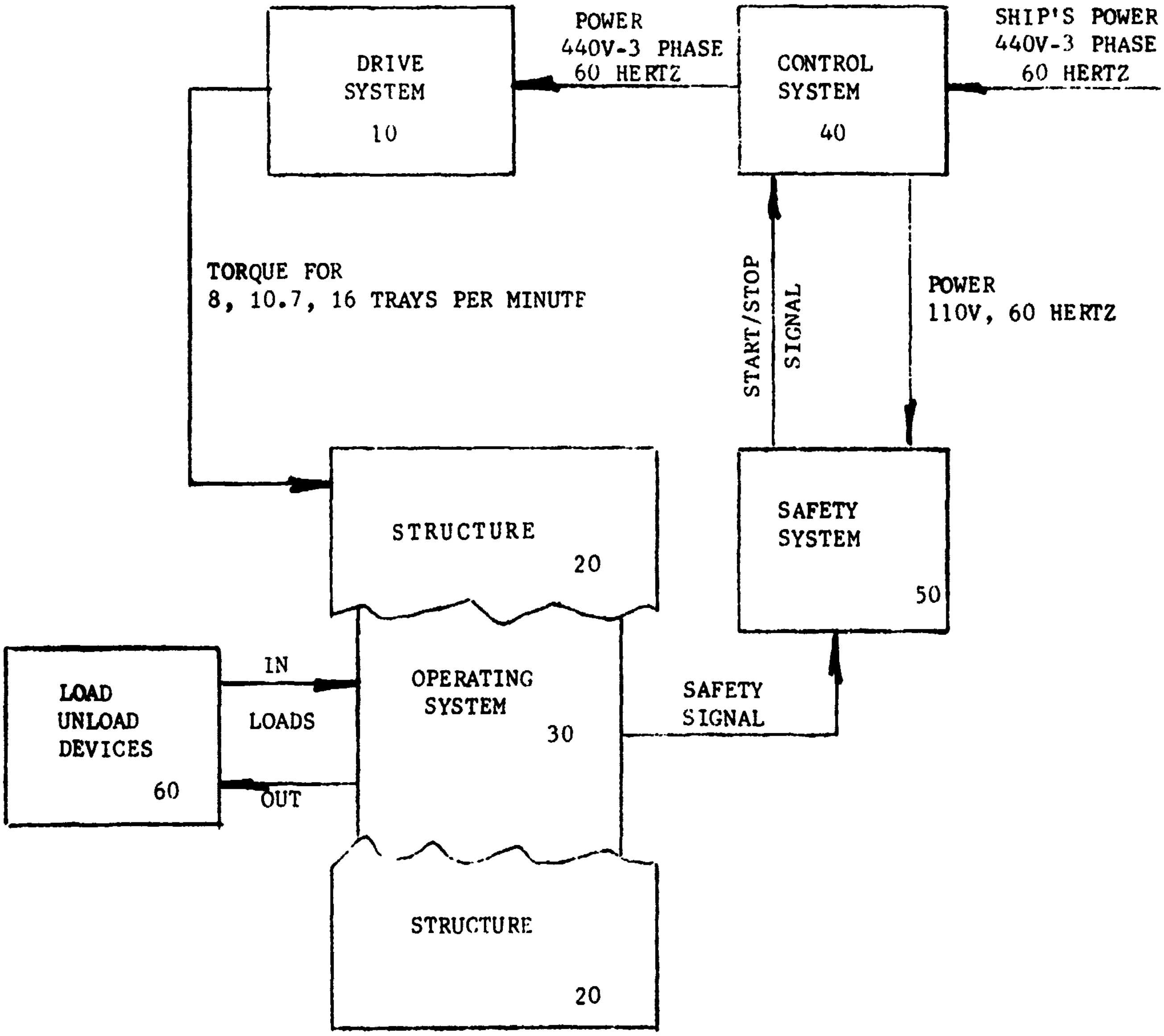
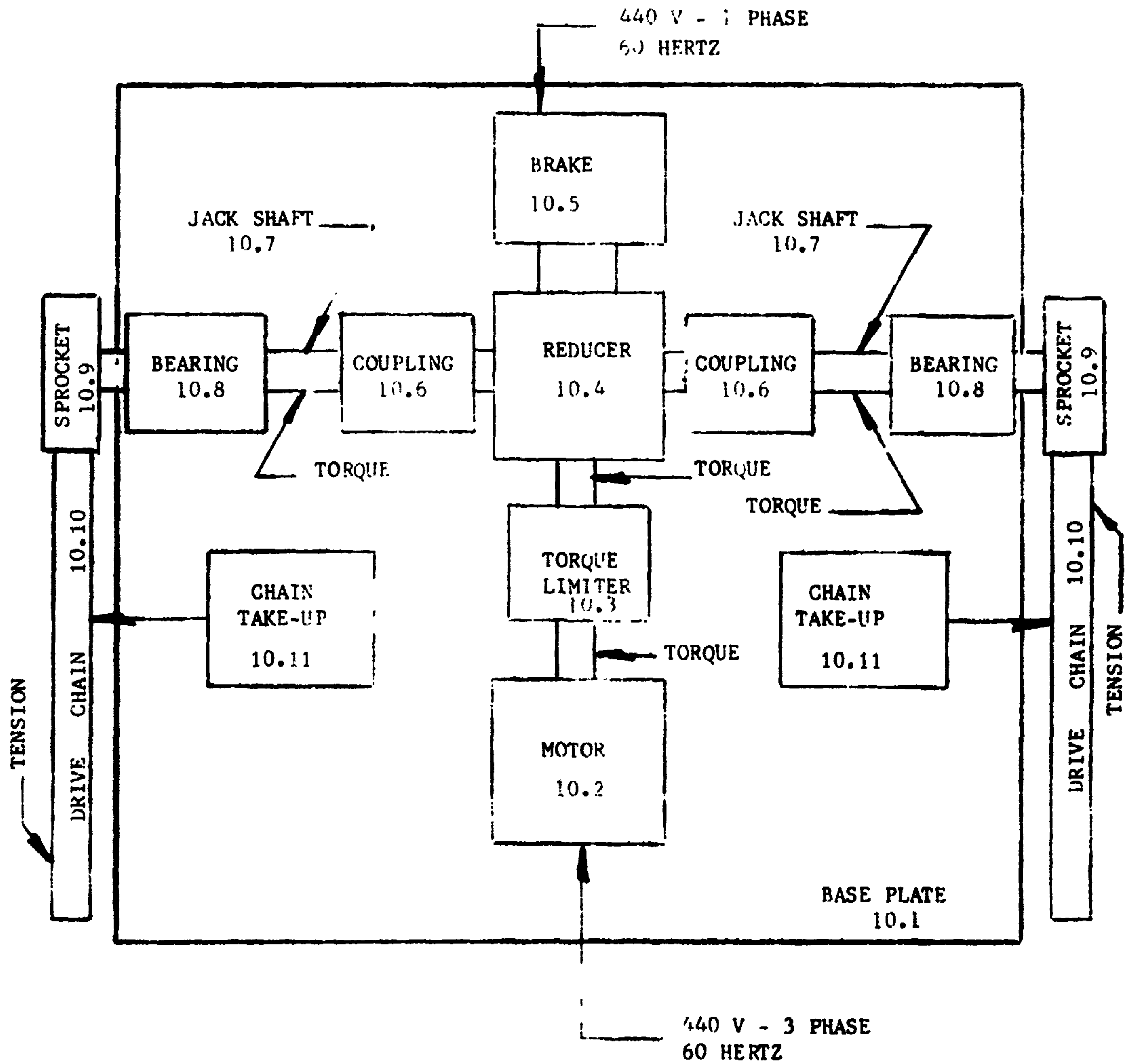


FIGURE NO. 1 Second indenture level functional block diagram.



NOTE: All components are sized and rated as a function of conveyor loading.

FIGURE NO. 2 Third indentured level functional block diagram for drive system (Number 10)

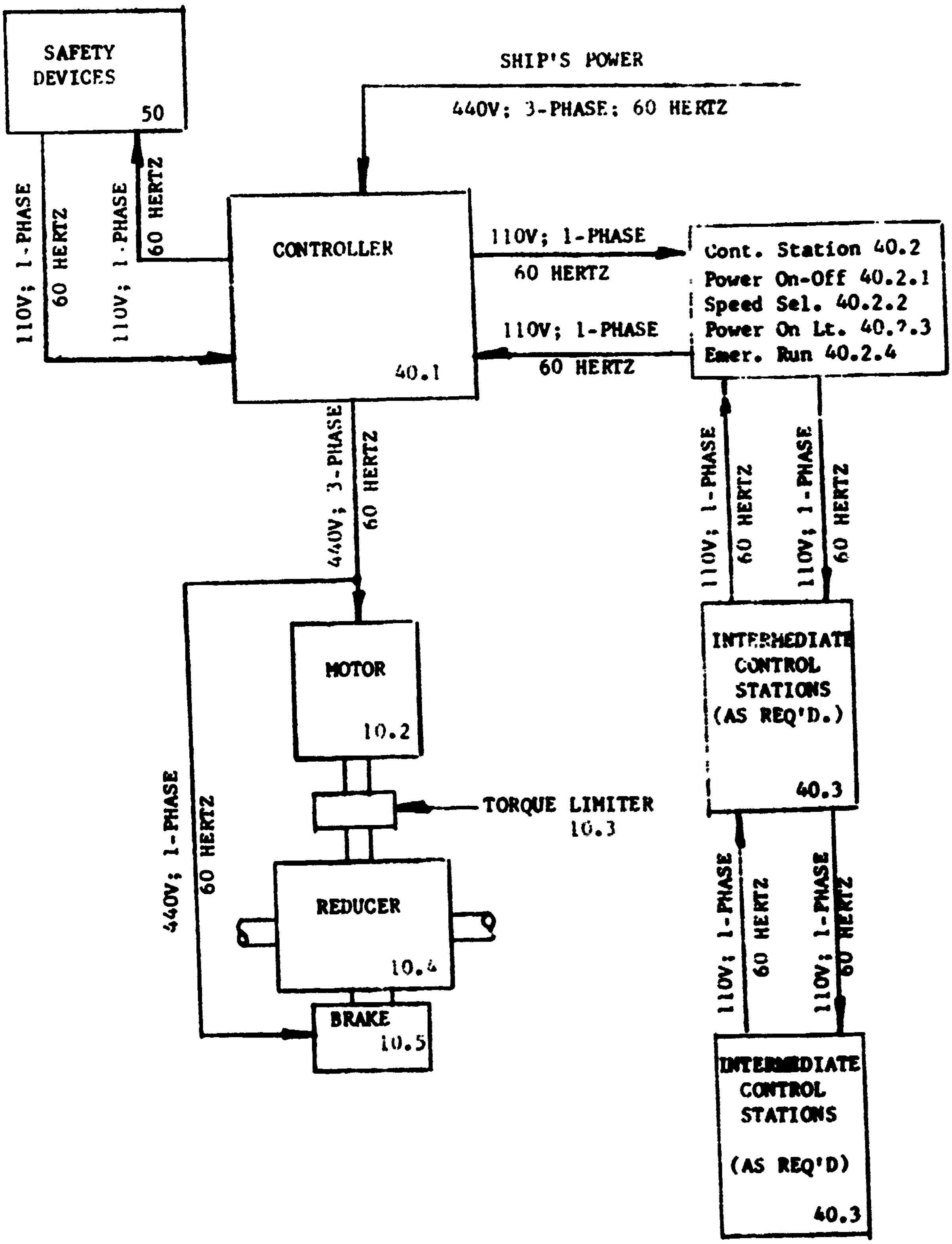


FIGURE NO. 4 Third indentured level functional block diagram for the control system (Number 40).

to the outside of the trunk at the deck levels serviced. The Contractor is not planning to perform failure modes and effects analysis on the Structure Sub-system.

3.2.3 Sub-system Number 30 - Operating System

The operating system consists of those parts which lift and lower the loads. The loads are positioned on "carriers" attached to a "carrier chain" supported by head and tail sprockets. The carriers operate in tracks which guide the carriers and which tilt the carriers from the horizontal flat position for load carrying to the vertical position for return at the back of the conveyor. The load area is separated from the return area by back shields The operating system consists of:

- Number 30.1 - Head cam plate
- Number 30.2 - Head shaft
- Number 30.3 - Head shaft bearings
- Number 30.4 - Head bearing housing
- Number 30.5 - Head shaft sprocket
- Number 30.6 - Carrier chain section
- Number 30.7 - Carrier link
- Number 30.8 - Chain pin
- Number 30.9 - Carrier shaft
- Number 30.10 - Guide arm
- Number 30.11 - Cuide arm cap
- Number 30.12 - Cam follower - flanged
- Number 30.13 - Cam follower
- Number 30.14 - Carrier
- Number 30.15 - Front track
- Number 30.16 - Rear track
- Number 30.17 - Tail cam plate

Number 30.18	-	Tail carrier sprocket
Number 30.19	-	Tail sprocket bearings
Number 30.20	-	Chain take-up
Number 30.21	-	Head driven sprocket

The functional interrelationship between the components of the operating system is shown on Figure No. 3.

3.2.4 Sub-system Number 40 - Control System

The control systems consists of the controller, the master station, the machinery area station and intermediate control stations located at each ship's level serviced by the conveyor. The controller passes ships power at 440 Volts, 3-phase, 60 hertz through relays to the conveyor motor and brake. The relays are operated by the master, machinery and intermediate stations to start or stop the conveyor. The master station selects which of the stations will be in control, the speed of the conveyor, and, the direction of motion - up or down. The machinery station is equipped with a jog switch allowing intermittent motion of the conveyor in either the up or down direction to facilitate maintenance and repair. Safety devices (see par. 3.2.5) operate to stop the conveyor by interrupting power to the motor and brake. The brake is "fail safe" in that the brake is "on" when the power is "off". Both the motor and the brake will be analyzed as part of the Drive System (Number 10); they are included here to complete the electrical circuitry diagram. Elements of the Control system are:

Number 40.1	-	Controller
Number 40.2	-	Master station
Number 40.3	-	Machinery station
Number 40.4	-	Intermediate station(s)

The functional interrelationship between the elements of the control system is shown in Figure No. 4.

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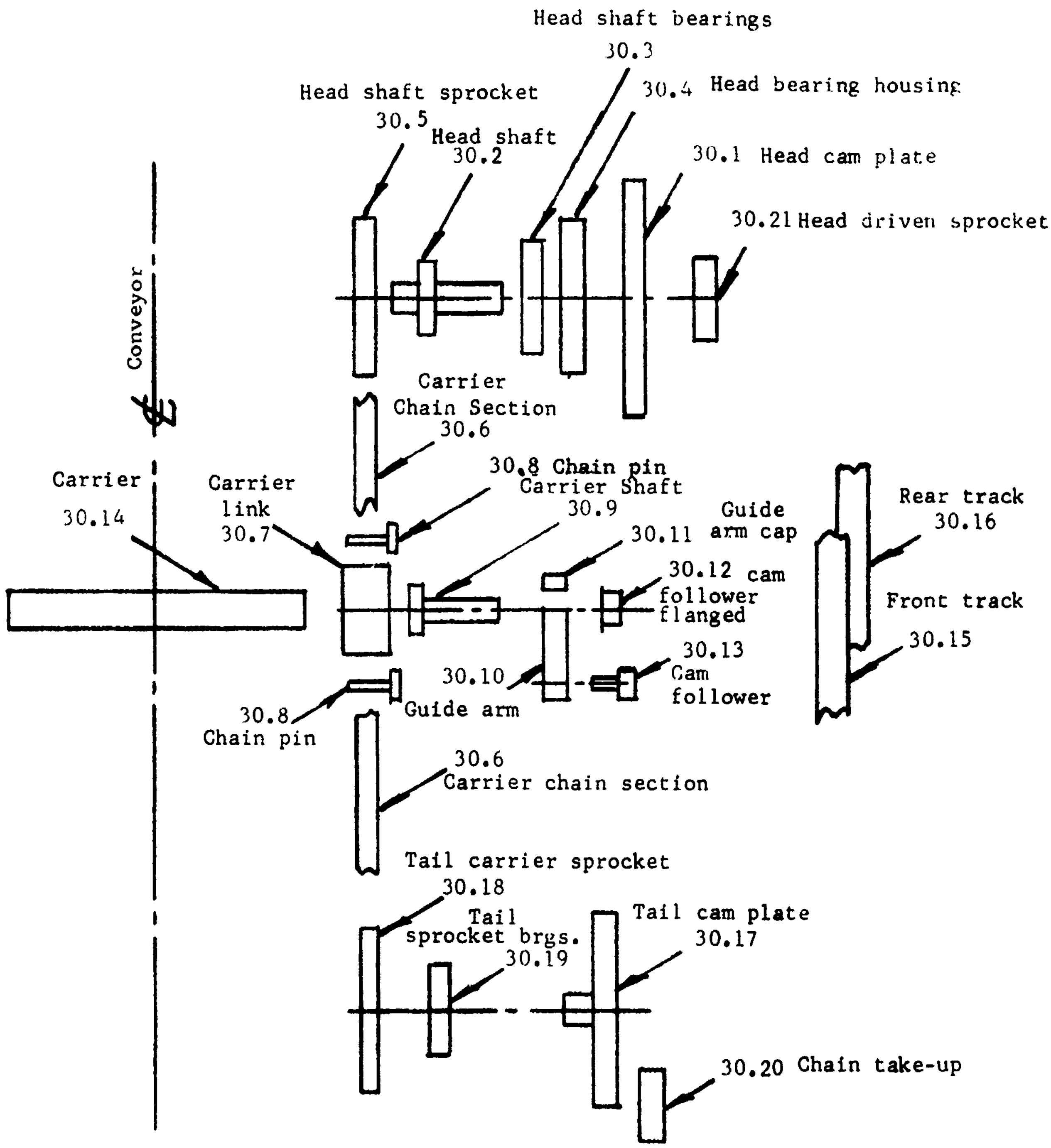

FIGURE NO. 3 Third indentured level functional block diagram for operating system (Number 30)

3.2.4.1 <u>Controller.</u> The controller performs the function of housing the 3-speed motor reversing starter, the instant overload relay (IOL) and by-pass timer, the thermal overload device, the emergency run button, the audio signal timer, three relays activated by the safety devices (Number 50, par. 3.2.5), and three relays activated by the speed selector switch (Number 40.2, par. 3.2.4). The controller receives ship's power and, at the command of the controlling stations and the safety devices, turns the motor on or off. The controller is usually mounted in a secure but accessible location either on the ship's bulkhead or on the trunk of the conveyor. All elements of the controller are replaceable. These elements consist of:

Number 40.1.1 - 3-speed reversing starter

Number 40.1.2 - Thermal overload device

Number 40.1.3 - Emergency run switch

Number 40.1.4 - Instant overload relay (IOL)

Number 40.1.5 - IOL by-pass timer

Number 40.1.6 - 440V to 110V transformer

Number 40.1.7 - 1st speed relay

Number 40.1.8 - 2nd speed relay

Number 40.1.9 - 3rd speed relay

Number 40.1.10 - Over-the-door jam sensing relay

Number 40.1.11 - Loader/unloader interlock and jam sensing relay

Number 40.1.12 - Door interlock relay

Number 40.1.13 - Audio signal timer

The functional interrelationships between these elements, the safety devices, and the control system is shown in Figure No. 5.

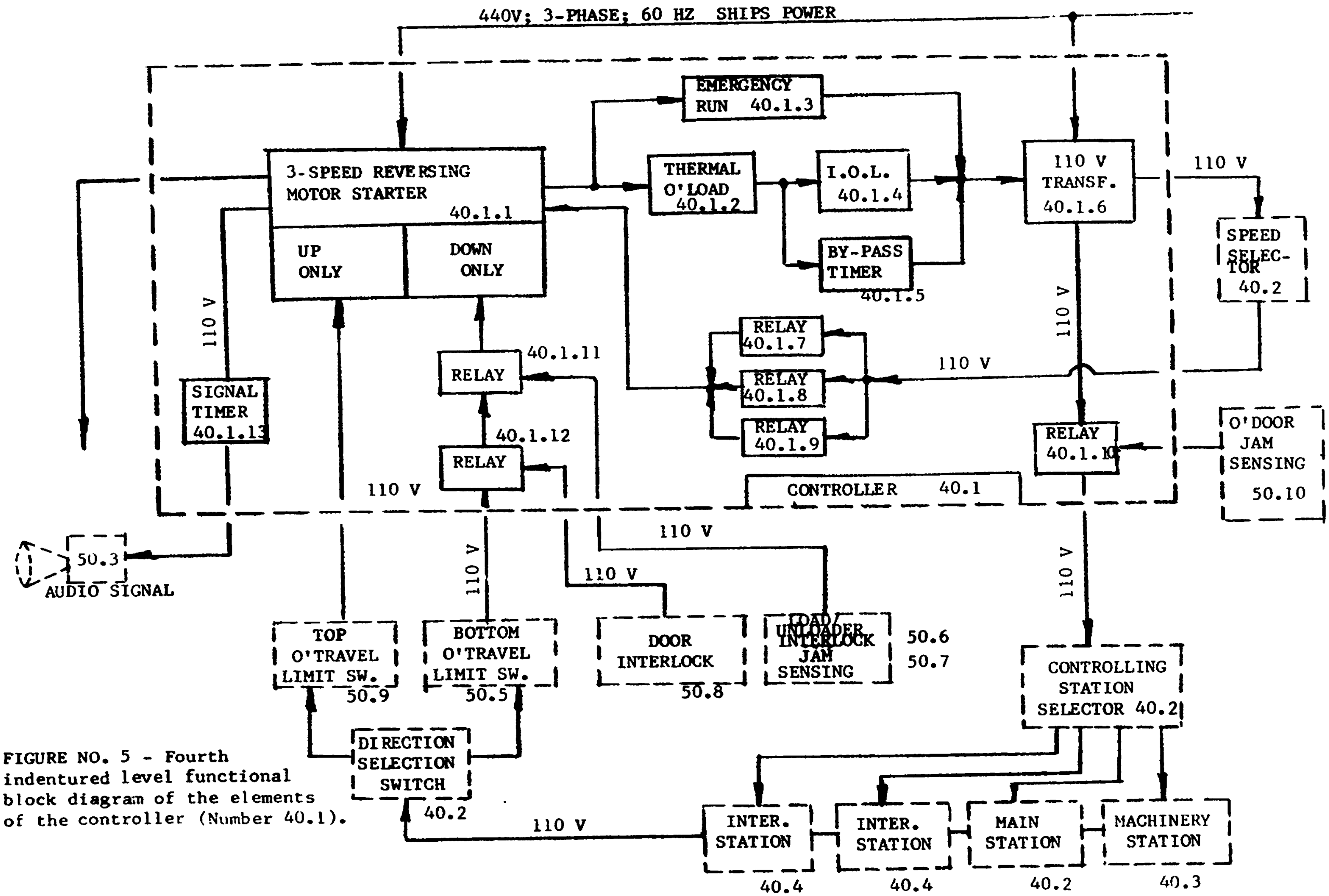

FIGURE NO. 5 - Fourth indentured level functional block diagram of the elements of the controller (Number 40.1).

3.2.4.2 Number 40.2 - Master control station. The master control station performs the function of turning power on to power itself and all other stations. Power "on" is indicated by a green light. The master control station also selects one of three motor speeds, the direction of motion, and, which station will control the conveyor. All elements are replaceable. The master control station is usually mounted on the conveyor trunk, at the main deck level. Elements consist of:

- Number 40.2.1 - Power on/off selector switch
- Number 40.2.2 - Three position speed selector switch
- Number 40.2.3 - Two position conveyor motion switch (up/down)
- Number 40.2.4 - One or more three position station selector switches

3.2.4.3 Number 40.3 - Machinery station. The machinery station is located in the machinery area to enable maintenance and repair personnel to operate the conveyor. All elements are replaceable. This station is equipped with:

- Number 40.3.1 - Green power - on light
- Number 40.3.2 - Start button
- Number 40.3.3 - Stop/run switch
- Number 40.3.4 - Jog switch

3.2.4.4 Number 40.4 - Intermediate stations. All intermediate stations are identically equipped and are the same as the machinery station except they have no jog switch. Functions are to start and to stop the conveyor during strike-up operation or should an emergency arise. Any intermediate station can stop the conveyor; all stop/run switches must be in the run position for the conveyor to operate.

3.2.5 Sub-System number 50 - Safety devices

Safety devices may be considered in the following general categories:

1) motor protection

2) personnel protection

3) protection against conveyor damage due to jamming

Following is a brief description of each safety device identifying function and the category into which the safety device fits.

Number 50.1 - Instantaneous overload - motor protection - allows an initial amperage surge for start-up - cuts off power if following amperage surges exceed a pre-set value.

Number 50.2 - Thermal overload - motor protection - cuts off power if motor amperage develops sufficient heat to exceed a pre-set value.

Number 50.3 - Audio signal - personnel protection - sounds an audio signal at each level warning personnel that the conveyor is about to start - operates automatically for 2 to 3 seconds after the start action has been initiated but before the conveyor actually runs.

Number 50.4 - Brake - personnel protection - stops the conveyor within narrow limits whenever power is cut-off. Prevents the conveyor from back-traveling even though the conveyor is equipped with a non-overhauling reducer.

Number 50.5 - Bottom overtravel - conveyor protection - prevents packages passing through and jamming at the bottom of the conveyor - senses incipient jamming - operates during strike-down only.

Number 50.6 - Loader/unloader interlock - conveyor protection - prevents strike-down operation should the loader/unloader be in the horizontal load position instead of the tilted, unload, position - operates during strike-down.

Number 50.7 - Loader/unloader jam sensing - conveyor protection - stops the conveyor should a down coming tray strike a package not completely ejected after the package has depressed the loader/unloader a pre-set distance - senses incipient jamming - operates during strike-down.

Number 50.8 - Door interlock - conveyor protection - prevents strike-down operation unless the door at the unload station is fully open.

Number 50.9 - Top overtravel - conveyor protection prevents packages passing through and jamming at the top of the conveyor - senses incipient jamming - operates during strike-up only.

Number 50.10 - Over-the-door-jam sensing - conveyor protection - stops the conveyor if disturbed by a misplaced package - most effective in preventing package jamming between the tray and the upper door coaming-senses incipient jamming - operates during strike-up and strike-down.

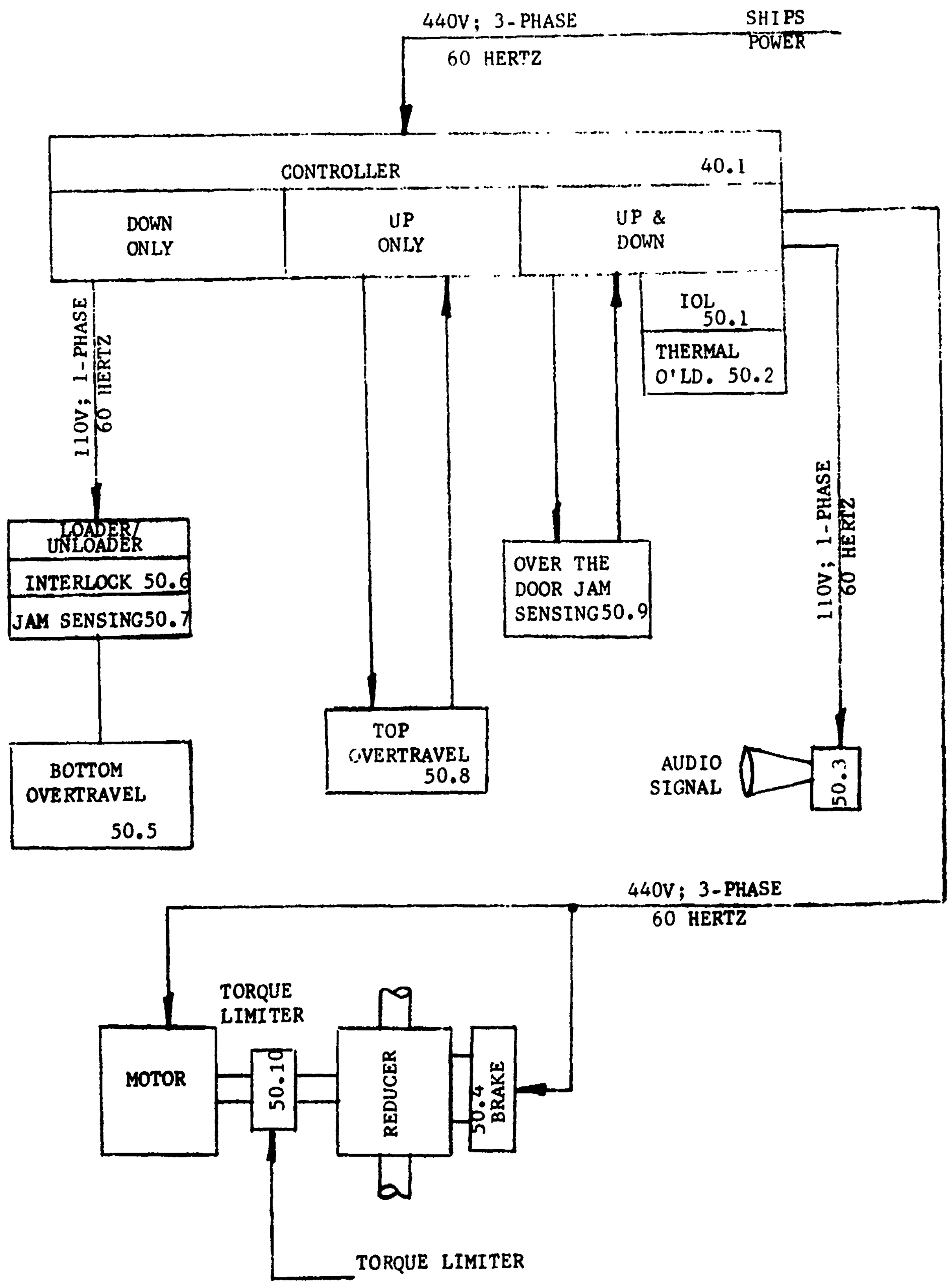

FIGURE NO. 6 - Third indentured level functional block diagram for safety devices (Number 50).

Number 50.11 - Torque limiter - conveyor protection - set to slip at 110 to 115% of total load - operates continuously - will prevent conveyor and motor damage should all other devices fail.

The functional interrelationships between the safety devices are shown on Figure No. 6.

3.2.6 Sub-System Number 60 - Load/unload devices

Load/unload devices are supplied to enable the operators to conveniently load and unload packages into and out-of the conveyor. They may be positioned in one of three ways:

Load - horizontal to enable operators to place packages on the fingers of the load/unload device. The fingers of the tray pass between the fingers of the load/unload device and pick-up the package,carrying the package up. A safety interlock (Figure 4, 50.6) prevents strike-down operation when the load/unload device is in the "load" position. Usually simple wheel type conveying sections are hooked-to the load/unload device so that packages may be rapidly on-loaded.

Unload - tilted about 30° from the horizontal. Packages carried by the trays strike the fingers of the load/unload device and slide out of the load area of the conveyor. Usually simple wheel type conveying sections are hooked-to the load/unload device so that packages may be rapidly removed from the door opening. A door interlock (Figure 4, 50.8) is included at each serviced level to assure that the door is fully open at the unload station before the conveyor will operate in the strike-down mode.

Stowed - vertical either up or down. When the load/unload device is in the stowed downward position, loads may be unloaded from that station during strike-up operation. At times it is preferable to stow the load/unload device in the upward position where it acts as a personnel guard. Stowing upward or downward is an option of the procuring activity.

The load/unload device incorporates two additional safety features:

<u>one</u> - the fingers of the load/unload device are spring loaded and are capable of being depressed should a downcoming tray strike and press against a package inadvertently not removed from the package area. As the fingers of the load/unload device depress a micro-switch is activated which immediately cuts-off conveyor power.

<u>two</u> - the load/unload device is arranged to "hinge" when the device is in the load or unload positions. Thus, in the event packages strike the bottom of the load/unload device, the device will hinge upward and toward the door opening, out of the way of the upcoming package.

The functional interrelationship between the elements of the load/unload device is shown in Figure No. 7. These elements consist of:

Number 60.1 - Platform
Number 60.2 - Mtg. and stowing bracket R.H.
Number 60.3 - Mtg. and stowing bracket L.H.
Number 60.4 - Platform depress mechanism L.H.
Number 60.5 - Platform depress mechanism R.H.
Number 60.6 - Cross shaft
Number 60.7 - Interlock microswitch
Number 60.8 - Jam sensing microswitch

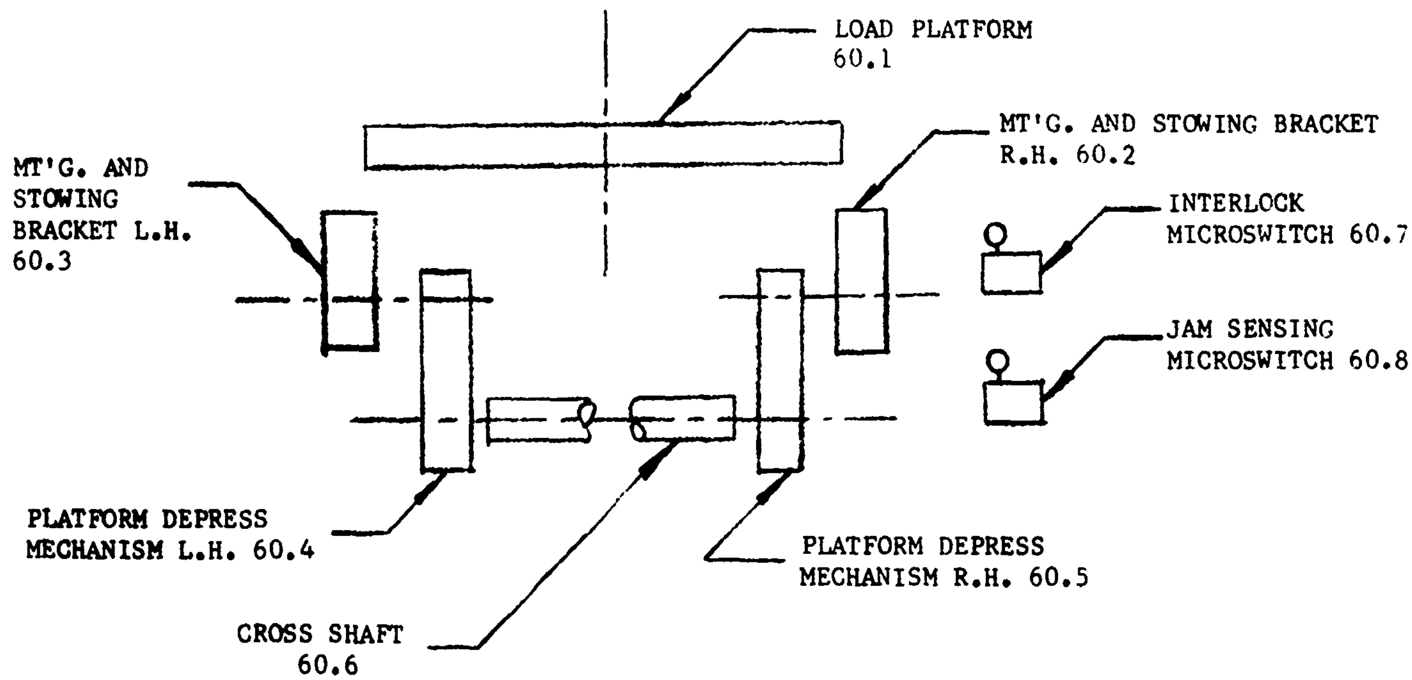

FIGURE NO. 7 - Third level indentured functional block diagram for the load/unload device (Number 60).

4. FMEA LIST

4.1 The list of items recommended for FMEA application is composed of all items listed in the following paragraphs:

Paragraph: 3.2.1

Paragraph: 3.2.3

Paragraph: 3.2.4.1

Paragraph: 3.2.4.2

Paragraph: 3.2.4.3

Paragraph: 3.2.5

Paragraph: 3.2.6

5. FMEA DEPTH

5.1 The FMEA analysis will be performed on each major assembly and sub-assembly of the functional systems identified in paragraph 3.2, to the depth necessary to identify replaceable parts and components composing the assemblies and sub-assemblies.

6. FAILURE MODES

6.1 The Contractor analyzed data supplied by the Navy's Maintenance Support Office (MSO) Material History Report, MSO No. 479052704.A07, Volumes 1 and 2. This data covered 10 manufacturers of vertical stores conveyors during the period between January 1, 1970 thru April 1972 (2-1/3 years). The data described failures which occurred on 132 vertical stores conveyors ranging in capacity from 85 to 4,000 pounds per tray. The Contractor's report provided a statistical interpretation of this data and included a "corrective action plan". The report titled,"Reliability Studies Including Corrective Action Plan for Vertical Package Conveyor" was submitted to NAVSEC August 10, 1972. To the Contractor's knowledge no more valid source of data identifying the failures occurring to parts and systems of vertical stores conveyors is anywhere else available.

6.2 The report identified above provides a valid statistical base for the selecting failure modes. The FMEA alysis, which will be performed as required by CDRL item B001AH, will analyze each item, system, or sub-system, of paragraph 4.1 and will use the work sheet shown as Figure 2 of MIL-STD-1629 (Ships) as the basic analysis tool. Failure modes for each of the items selected for analysis will be provided in the FMEA report.

7. CRITERIA FOR IDENTIFYING CRITICAL ITEMS

7.1 Criticality of the effect of item failure will be established using the techniques outlined in MIL-STD-1629 (Ships), par. 5.11 and 5.11.1.

7.1.1 Criticality is defined as the combination of probability of occurrence and the level of severity. A criticality matrix will be used as the means of identifying and comparing each failure mode to all other failure modes with respect to the ship's mission and the items functional output and maintenance.

7.1.1.1 Severity is classified as follows: (MIL-STD-1629 SHIPS, par. 5.9.1)

(a) Level 1, minor. Characterized by any one or combinations of the following conditions:

(1) No effect on ship's mission capability.

(2) Negligible effect on functional output of the item at the initial indenture level.

(3) Other indenture level item degradation that can be repaired by performing "adjustment type" maintenance.

(b) Level 2, major. Characterized by any one or combinations of the following conditions:

(1) Negligible effect on ship's mission capability.

(2) Degradation in functional output of the item at the initial indenture level.

(3) Other indenture level item failure that can be repaired immediately within the capability of organization level maintenance.

(c) Level 3, critical. Characterized by any one or combinations of the following conditions:

(1) Some degradation in ship's mission capability.

(2) Severe reduction in functional output of the item at the initial indenture level.

(3) Other indenture level item failure that cannot be repaired immediately within the capability of organizational (shipboard) level maintenance.

(d) Level 4, catastrophic. Characterized by any one or combinations of the following conditions:

(1) Severe reduction in ship's mission capability.

(2) Complete functional output loss of the item at the initial indenture level.

(3) Other indenture level item failure requiring tender or depot maintenance repair.

The level of severity selected shall be the highest level an item falls under, regardless of whether a lower classification is also applicable.

7.1.1.2 Failure probability shall be assessed in both quantitative and qualitative terms (MIL-STD-1629 (SHIPS), par. 5.10, 5.10.1, 5,10,2, 5.10.2.1 and 5.10.2.2).

Failure probability level guidlines.

Qualitative. The following sample guidelines are suggested for developing definitions for failure probability levels in qualitative terms:

(a) Level 1 - Failure mode probability very low. A negligible chance of occurrence during the item operating time interval.

(b) Level 2 - Failure mode probability low. An unlikely chance of occurrence during item operating time interval.

(c) Level 3 - Failure mode probability medium. A random fifty/fifty chance of occurrence during item operating time interval.

(d) Level 4 - Failure mode probability high. A likely change of occurrence during the item operating time interval.

Quantitative. The following sample guidelines are suggested for developing definitions for failure probability levels in quantitative terms:

(a) Level 1 (very low). Any single failure mode probability of occurrence which is less than 0.01 of the overall probability of failure during the item operating time interval.

(b) Level 2 (low). Any single failure mode probability of occurrence which is more than 0.01 but less than 0.10 of the overall probability of failure during the item operating time interval.

(c) Level 3 (medium). Any single failure mode probability of occurrence which is more than 0.10 but less than 0.20 of the overall probability of failure during the item operating time interval.

(d) Level 4 (high). Any single failure mode probability of occurrence which is more than 0.20 of the overall probability of failure during the item operating time interval.

These recommended definitions shall be modified or expanded as necessary, depending on the system or equipment being analyzed and the amount of failure data available for the type of hardware involved.

8. FMEA ITEM SELECTION RATIONAL

8.1 The items selected for FMEA analysis were selected based on the following rational:

(a) any item the failure of which would prevent conveyor operation,

(b) any item the failure of which would affect the operation of another system or sub-system. Example: failure of the loader/unloader micro-switch jam sensing switch would not prevent or interfere with conveyor operation. However, should a jam occur, the micro-switch would fail to operate and serious damage could result since motor current would continue until either

- cut-off by the IOL,
- cut-off by the thermal overload protection device

Failure of these systems to function would eventually force the torque limiter to slip.

(c) any item the failure of which should be repaired to continue efficient conveyor operation or to minimize the possibility of eventual damage or wear to other systems, sub-systems or components. Example: freeze-up of a guide arm cam follower. By itself this failure is not overly detrimental, however, the frozen bearing would slide instead of roll along the track causing eventual wear to the track and bottom and top cam plates. Additional power would be required. If enough cam followers failed, wear would be rapid and power would exceed the limits of the IOL or thermal overload causing these devices to cut motor current.

Failure Mode and Effects Analysis Report
DD 1423
Item B001AH

(Partial Fulfillment of Line Item 004
Re Contract No. N00024-72-C-5500)

Copies: Six

Reproducibles: None

Submitted: Commander, Naval Ship
Engineering Center
Center Building Prince George Center
Hyattsville, Maryland 20782
Code 6164

ATTENTION: Mr. Satterthwaite
COPY TO: Mr. Otto

Submittal Date: March 24, 1976

Failure Modes and Effects Analysis Report

(CDRL Item B001AH)

March 24, 1976

R. A. Larson, Controller

Kornylak Corporation
Hamilton, Ohio

Introduction

This Failure and Effects Analysis Report has been prepared by the Kornylak Corporation, 400 Heaton Street, Hamilton, Ohio 45211 as a response to Contractor Data Requirement List Item B001AH of USN Contract N00024-72-C-5500.

The report covers the modes and effects of potential failure of significant parts, components, sub-assemblies and assemblies designed for incorporation into a "hi-reliability" vertical stores conveyor per contractural specification Ships-C-5552. Specifically this report has been prepared in accord with paragraphs 3.2.5, 3.2.5.1 and 3.2.5.2 of Ships-C-5552. The format of the report relies on MIL-STD-1629 titled "Procedures for Performing a Failure and Effects Analysis for Shipboard Equipment" provided to the contractor by Naval Ships Engineering Center for this purpose.

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Failure Modes and Effects Analysis Report

1. SCOPE

1.1 The Failure Modes and Effects Analysis (FMEA) Report contains:

(a) A narrative functional description of the vertical stores conveyor.

(b) A functional block diagram.

(c) An indentured block diagram detailed down to the indentured level which will identify replaceable parts or components.

(d) A list of the items recommended for FMEA application.

(e) An outline of the depth of which FMEA will be applied within each assembly and sub-assembly.

(f) A description of the type of failure modes associated with each item selected for FMEA application.

(g) A description of the criteria to be used for identifying critical items (MIL-STD-1629 [Ships] will be used as applicable).

(h) The rationale for selecting the items and associated failure modes for FMEA.

(i) A complete FMEA of the vertical stores conveyor including analysis, working papers, criticality matrix and criticality tabulation.

2. APPLICABLE DOCUMENTS

2.1 To the extent applicable, the following documents will be used to prepare and support this report:

Standards:

MIL-STD-470 - Maintainability Program Requirements (for Systems and Equipment)

MIL-STD-785 - Reliability Program for Systems and Equipment Development and Production

MIL-STD-1629 (Ships) - Procedures for Performing a Failure Mode and Effect Analysis for Shipboard Equipment

Reports:

"Reliability and Maintainability Program Plans - Final" (prepared by Kornylak Corporation and submitted January 28, 1975 under CDRL Item B001AA of USN Contract N00024-72-C-5500).

"Reliability Studies Including Corrective Action Plan for Vertical Package Conveyor" (prepared by Kornylak Corporation and submitted August 10, 1972 under CDRL Item A001AG-1 of USN Contract N00024-72-C-5500).

FMEA Selection and Criteria Report (prepared by Kornylak Corporation and submitted April 10, 1975 under CDRL Item B001AB of USN Contract N00024-72-C-5500).

3. EQUIPMENT DESCRIPTION AND FUNCTIONAL BLOCK DIAGRAM

3.1 Narrative Functional Description. The vertical stores conveyor is used to convey goods and stores from one ship's level to another. The conveyor is equipped with vertically moving trays to carry packages weighing up to 100 pounds in size and up to 36 inches wide by 24 inches deep by 36 inches high. Each load station is equipped with platforms that can be positioned to mechanically eject packages at that load station; these devices can also be positioned as a load platform to position loads for pick-up during strike-up operation. Speed of operatio.. can be selected at eight, 10.7 and 16 trays per minute. The machine is electrically motor-driven through a non-overhauling reducer. An electrical brake is used to stop conveyor motion. The conveyor is controlled through a series of push-button stations located at each load station. The function of turning power "on" and selecting conveyor speed is located at the "Controller" which also houses the starting relays, safety relays and other electrical equipment. Safety devices are incorporated to protect the motor against overload and which sense incipient package jams in order to stop the conveyor. An audio signal warns the operator that the conveyor is about to start.

3.2 Functional Block Diagram. The following block diagram and block diagram sub-systems provide the structural data for the FMEA.

Number 100	Vertical Conveyor System
Number 10	Drive System
Number 20	Structure
Number 30	Operating System
Number 40	Control System
Number 50	Safety Devices
Number 60	Load/Unload Devices

The functional interrelationships between these devices and sub-systems is shown on Figure No. 1.

3.2.1 Sub-system Number 10 - Drive System. The drive system powers the conveyor through a chain and sprocket system. The drive sprocket and chain are considered part of the drive system. the rest of the system consists of:

Number 10.1	Base Plate
Number 10.2	Motor
Number 10.3	Torque Limiter
Number 10.4	Reducer
Number 10.5	Brake
Number 10.6	Jack Shaft Coupling
Number 10.7	Jack Shaft
Number 10.8	Pillow Block Bearing
Number 10.9	Drive Sprockets and Keys
Number 10.10	Drive Chain
Number 10.11	Drive Chain Take-up

The drive system may be mounted on the back, left side or right side - as selected by the procuring activity. The functional interrelationship between the components of the drive system is shown on Figure No. 2.

3.2.2 Sub-system Number 20 - Structure. The structure consists of the conveyor trunk or frame, door frames and doors, and various internal shields. The trunk or frame is the basic supporting and mounting structure for the drive system and all operating elements. The door frame is fastened to the trunk (not the frame of frame types) and supports the door hinging and "dogging" mechanism. A variety of shields are included as "structure" although they do not contribute to conveyor support. These shields guard the package area and the operating mechanism. The structure consists of:

Number 20.1	Trunk (or Frame)
Number 20.2	Door Framing
Number 20.3	Shields

3.2.2.1 The main structure or trunk of the conveyor is sized to adequately support the drive system, operating system, shields, door frames and operating loads. The trunk is also sized to withstand whatever water pressure head is specified by the procuring activity. The trunk is permanently welded to the ship's deck and becomes a part of the ship's structure. The trunk consists of welded plates forming a rectangular box of a length necessary to service the deck levels specified. The shields are formed sheet steel bolted or welded to the trunk by suitable supports and/or bracketry. Door frames are welded to the outside of the trunk at the deck levels serviced. The Contractor is not planning to perform failure modes and effects analysis on the Structure Sub-system except in compliance with NAVSEC letter Ser. #367 dated 21 May 1975, paragraphs 1.b(2) and (3). (Note: paragraph 1-b(1) is a shipyard installation problem beyond the Contractor's control).

3.2.3 <u>Sub-system Number 30 - Operating System</u>. The operating system consists of those parts which lift and lower the loads. The loads are positioned on "carriers" attached to a "carrier chain" supported by head and tail sprockets. The carriers operate in tracks which guide the carriers and which tilt the carriers from the horizontal flat position for load carrying to the vertical position for return at the back of the conveyor. The load area is separated from the return area by back shields. The operating system consists of:

Number 30.1	Head Cam Plate
Number 30.2	Head Shaft
Number 30.3	Head Shaft Bearings
Number 30.4	Head Bearing Housing
Number 30.5	Head Shaft Sprocket
Number 30.6	Carrier Chain Section
Number 30.7	Carrier Link
Number 30.8	Chain Pin
Number 30.9	Carrier Shaft
Number 30.10	Guide Arm
Number 30.11	Guide Arm Cap
Number 30.12	Cam Follower - Flanged
Number 30.13	Cam Follower
Number 30.14	Carrier
Number 30.15	Front Track
Number 30.16	Rear Track
Number 30.17	Tail Cam Plate
Number 30.18	Tail Carrier Sprocket
Number 30.19	Tail Sprocket Bearings
Number 30.20	Chain Take-up
Number 30.21	Head Driven Sprocket

The functional interrelationship between the components of the operating system is shown on Figure No. 3.

3.2.4 Sub-system Number 40 - Control System. The control systems consist of the Controller and intermediate control stations located at each ship's level serviced by the conveyor and in the machine area. The Controller passes ship's power at 440 Volts, three-phase, 60 hertz through relays to the motor and brake. The relays are operated by controls at the intermediate stations to start or stop the conveyor. Switches located in the Controller turn power on or off to the control stations and select the speed of the conveyor. Safety devices (see paragraph 3.2.5) operate to stop the conveyor by interrupting power to the motor and brake. The brake is "fail safe" in that the brake is "on" when the power is "off". Both the motor and the brake will be analyzed as part of the Drive System (Number 10); they are included here to complete the electrical circuitry diagram. Elements of the Control System are:

Number 40.1	Controller
Number 40.2	Controller Station
Number 40.3	Intermediate Station (s)

The functional interrelationship between the elements of the control system is shown in Figure No. 4.

3.2.4.1 Controller. The Controller performs the function of housing the three-speed motor reversing starter, the instant overload relay (IOL) and by-pass timer, three relays activated by the safety devices (Number 50, paragraph 3.2.5), and three relays activated by the speed selector switch (Number 40.2.2, paragraph 3.2.4.2). The Controller receives ship's power and, at the command of the controlling stations and the safety devices, turns the motor on or off. The Controller is usually mounted in a secure but accessible location either on the ship's bulkhead or on the trunk of the conveyor. All elements of the Controller are replaceable. These elements consists of:

Number 40.1.1	Three-speed Reversing Starter
Number 40.1.2	Thermal Overload Device
Number 40.1.3	Instant Overload Relay (IOL)
Number 40.1.4	IOL By-pass Timer
Number 40.1.5	440 Volt to 110 Volt Transformer
Number 40.1.6	First Speed Relay
Number 40.1.7	Second Speed Relay
Number 40.1.8	Third Speed Relay
Number 40.1.9	Over-the-door Jam Sensing Relay
Number 40.1.10	Loader/Unloader Interlock and Jam Sensing Relay
Number 40.1.11	Audio Signal Timer

The functional interrrelationships between these elements, the safety devices, and the control system is shown in Figure No. 5.

3.2.4.2 <u>Number 40.2 - Controller Station</u>. The Controller station performs the function of turning power "on" to power all other stations. Power "on" is indicated by a red light. This station also houses the three-speed selector switch and the emergency run switch. All elements are replaceable. The emergency run switch by-passes the instantaneous overload and the thermal overload protecting the motor to allow emergency operation of the conveyor. Elements consist of:

Number 40.2.1	Power On/Off Selector Switch
Number 40.2.2	Three-position Speed Selector Switch
Number 40.2.3	Power "On" Light (Red)

Number 40.2.4 Emergency Run Switch

3.2.4.3 Number 40.3 - Intermediate Stations. All intermediate stations are identically equipped; an intermediate station is located in the machinery area to enable maintenance personnel to operate the conveyor. The intermediate stations function to designate conveyor direction, up or down, and to stop the conveyor in the event of an emergency. Any intermediate station can stop the conveyor; all "stop/on" switches must be in the "on" position for the conveyor to operate.

Number 40.3.1	Power "On" Light (Green)
Number 40.3.2	Stop Push - On Pull (Red Light on Stop)
Number 40.3.3	Up Push Button
Number 40.3.4	Down Push Button

3.2.5 Sub-system Number 50 - Safety Devices. Safety devices may be considered in the following general categories:

(1) Motor Protection

(2) Personnel Protection

(3) Protection Against Conveyor Damage Due To Jamming

Following is a brief description of each safety device identifying function and the category into which the safety device fits.

Number 50.1 - Instantaneous overload - motor protection - allows an initial amperage surge for start-up - cuts off power if following amperage surges exceed a pre-set value.

Number 50.2 - Thermal overload - motor protection - cuts off power if motor amperage develops sufficient heat to exceed a pre-set value.

Number 50.3 - Audio signal - personnel protection - sounds an audio signal at each level warning personnel that the conveyor is about to start - operates automatically for two to three seconds after the start action has been initiated but before the conveyor actually runs.

Number 50.4 - Brake - personnel protection - stops the conveyor within narrow limits whenever power is cut off. Prevents the conveyor from back-traveling even though the conveyor is equipped with a non-overhauling reducer.

Number 50.5 - Bottom overtravel - conveyor protection - prevents packages passing through and jamming at the bottom of the conveyor - senses incipient jamming - operates during strike-down only.

Number 50.6 - Loader/Unloader interlock - conveyor protection - prevents strike-down operation should the loader/unloader be in the horizontal load position instead of the tilted, unload, position - operates during strike-down.

Number 50.7 - Loader/Unloader jam sensing - conveyor protection - stops the conveyor should a down coming tray strike a package not completely ejected after the package has depressed the loader/unloader a pre-set distance - senses incipient jamming - operates during strike-down.

Number 50.8 - Top overtravel - conveyor protection-prevents packages passing through and jamming at the top of the conveyor - senses incipient jamming - operates during strike-up only.

Number 50.9 - Over-the-door-jam sensing - conveyor protection - stops the conveyor if disturbed by a misplaced package - most effective in preventing package jamming between the tray and the upper door coaming - senses incipient jamming - operates during strike-up and strike-down.

Number 50.10 - Torque limiter - conveyor protection - set to slip at 110 to 115% of total load - operates continuously - will prevent conveyor and motor damage should all other devices fail.

The functional interrelationships between the safety devices are shown on Figure No. 6.

3.2.6 Sub-system Number 60 - Load/Unload Devices. Load/Unload devices are supplied to enable the operators to conveniently load and unload packages into and out of the conveyor. They may be positioned in one of three ways:

Load - horizontal to enable operators to place packages on the fingers of the load/unload device. The fingers of the tray pass between the fingers of the load/unload device and pick up the package, carrying the package up. A safety interlock (Figure 6, 50.6) prevents strike-down operation when the load/unload device is in the "load" position. Usually simple wheel type conveying sections are hooked to the load/unload device so that packages may be rapidly on-loaded.

Unload - Tilted about 30 degrees from the horizontal. Packages carried by the trays strike the fingers of the load/unload device and slide out of the load area of the conveyor. Usually simple wheel type conveying sections are hooked to the load/unload device so that packages may be rapidly removed from the door opening.

Stowed - Vertical either up or down. When the load/unload device is in the stowed downward position, loads may be unloaded from that station during strike-up operation. At times it is preferable to stow the load/unload device in the upward position where it acts as a personnel guard. Stowing upward or downward is an option of the procuring activity.

The load/unload device incorporates two additional safety features:

One - The fingers of the load/unload device are spring loaded and are capable of being depressed should a downcoming tray strike and press against a package inadvertently not removed from the package area. As the fingers of the load/unload device depress a micro-switch is activated which immediately cuts off conveyor power.

Two - The load/unload device is arranged to "hinge" when the device is in the load or unload positions. Thus, in the event packages strike the bottom of the load/unload device, the device will hinge upward and toward the door opening, out of the way of the upcoming package.

The functional interrelationship between the elements of the load/unload device is shown in Figure No. 7. These elements consist of:

Number 60.1	Platform
Number 60.2	Mtg. and Stowing Bracket R.H.
Number 60.3	Mtg. and Stowing Bracket L.H.
Number 60.4	Platform Depress Mechanism L.H.
Number 60.5	Platform Depress Mechanism R.H.
Number 60.6	Cross Shaft
Number 60.7	Interlock Microswitch
Number 60.8	Jam Sensing Microswitch

4. FMEA LIST

4.1 The list of items recommended for FMEA application is composed of all items listed in the following paragraphs:

Paragraph: 3.2.1

Paragraph: 3.2.2

Paragraph: 3.2.3

Paragraph: 3.2.4.1

Paragraph: 3.2.4.2

Paragraph: 3.2.4.3

Paragraph: 3.2.5

Paragraph 3.2.6

5. FMEA DEPTH

5.1 The FMEA analysis will be performed on each major assembly and sub-assembly of the functional systems identified in Paragraph 3.2, to the depth necessary to identify replaceable parts and components composing the assemblies and sub-assemblies.

6. FAILURE MODES

6.1 The Contractor analyzed data supplied by the Navy's Maintenance Support Office (MSO) Material History Report, MSO No. 479052704.A07, Volumes 1 and 2. This data covered 10 manufacturers of vertical stores conveyors during the period between January 1, 1970 through April, 1972 (2-1/3 years). The data described failures which occurred on 132 vertical stores conveyors ranging in capacity from 85 to 4,000 pounds per tray. The Contractor's report provided a statistical interpretation of this data and included a "corrective action plan". The report titled, "Reliability Studies Including Corrective Action Plan for Vertical Package Conveyor" was submitted to NAVSEC August 10, 1972. To the Contractor's knowledge no more valid source of data identifying the failures occurring to parts and systems of vertical stores conveyors is anywhere else available.

6.2 The report identified above provides a valid statistical base for the selecting failure modes. The FMEA analysis, which will be performed as required by CDRL Item B001AH, will analyze each item, system, or sub-system, of paragraph 4.1 and will use the work sheet shown as Figure 2 of MIL-STD-1629 (Ships) as the basic analysis tool. Failure modes for each of the items selected for analysis will be provided in the FMEA report.

7. CRITERIA FOR IDENTIFYING CRITICAL ITEMS

7.1 Criticality of the effect of item failure will be established using the techniques outlined in MIL-STD-1629 (Ships), paragraph 5.11 and 5.11.1.

7.1.1 Criticality is defined as the combination of probability of occurrence and the level of severity. A criticality matrix will be used as the means of identifying and comparing each failure mode to all other failure modes with respect to the ship's mission and the items functional output and maintenance.

7.1.1.1 Severity is classified as follows: (MIL-STD-1629 SHIPS, paragraph 5.9.1)

(a) Level 1, Minor. Characterized by any one or combinations of the following conditions:

(1) No effect on ship's mission capability.

(2) Negligible effect on functional output of the item at the initial indenture level.

(3) Other indenture level item degradation that can be repaired by performing "adjustment type" maintenance.

(b) Level 2, Major. Characterized by any one or combination of the following conditions:

(1) Negligible effect on ship's mission capability.

(2) Degradation in functional output of the item at the initial indenture level.

(3) Other indenture level item failure that can be repaired immediately within the capability

of organization level maintenance.

(c) Level 3, Critical. Characterized by any one or combination of the following conditions:

(1) Some degradation in ship's mission capability.

(2) Severe reduction in functional output of the item at the initial indenture level.

(3) Other indenture level item failure that cannot be repaired immediately within the capability of organizational (shipboard) level maintenance.

(d) Level 4, Catastrophic. Characterized by any one or combination of the following conditions:

(1) Severe reduction in ship's mission capability.

(2) Complete functional output loss of the item at the initial indenture level.

(3) Other indenture level item failure requiring tender or depot maintenance repair.

The level of severity selected shall be the highest level an item falls under, regardless of whether a lower classification is also applicable.

7.1.1.2 Failure probability shall be assessed in both quantitative and qualitative terms (MIL-STD-1629 [SHIPS], paragraphs 5.10, 5.10.1, 5.10.2, 5.10.2.1 and 5.10.2.2).

Failure Probability Level Guidlines

Qualitative. The following sample guidelines are suggested for developing definitions for failure probability levels in qualitative terms:

(a) Level 1 - Failure mode probability very low. A negligible chance of occurrence during the item operating time interval.

(b) Level 2 - Failure mode probability low. An unlikely chance of occurrence during item operating time interval.

(c) Level 3 - Failure mode probability medium. A random fifty/fifty chance of occurrence during item operating time interval.

(d) Level 4 - Failure mode probability high. A likely chance of occurrence during the item operating time interval.

Quantitative. The following sample guidelines are suggested for developing definitions for failure probability levels in quantitative terms:

(a) Level 1 - Very low. Any single failure mode probability of occurrence which is less than 0.01 of the overall probability of failure during the item operating time interval.

(b) Level 2 - Low. Any single failure mode probability of occurrence which is more than 0.01 but less than 0.10 of the overall probability of failure during the item operating time interval.

(c) Level 3 - Medium. Any single failure mode probability of occurrence which is more than 0.10 but less than 0.20 of the overall probability of failure during the item operating time interval.

(d) Level 4 - High. Any single failure mode probability of occurrence which is more than 0.20 of the overall probability of failure during the item operating time interval.

These recommended definitions shall be modified or expanded as necessary, depending on the system or equipment being analyzed and the amount of failure data available for the type of hardware involved.

8. FMEA ITEM SELECTION RATIONALE

8.1 The items selected for FMEA analysis were selected based on the following rationale:

(a) any item the failure of which would prevent conveyor operation,

(b) any item the failure of which would affect the operation of another system or sub-system. Example: failure of the loader/unloader microswitch jam sensing switch would not prevent or interfere with conveyor operation. However, should a jam occur, the microswitch would fail to operate and serious damage could result since motor current would continue until either

- cut-off by the IOL,
- cut-off by the thermal overload protection device.

Failure of these systems to function would eventually force the torque limiter to slip,

(c) any item the failure of which should be repaired to continue efficient conveyor operation or to minimize the possibility of eventual damage or wear to other systems, sub-systems or components. Example: freeze-up of a guide arm cam follower. By itself this failure is not overly detrimental, however, the frozen bearing would slide instead of roll along the track causing eventual wear to the track and bottom and top cam plates. Additional power would be required. If enough cam followers failed, wear would be rapid and power would exceed the limits of the IOL or thermal overload causing these devices to cut motor current.

9. <u>ANALYSIS</u>

The following sub-system analyses will cover only those failures which result in a frequency or severity level of three or four. In each case the recommended corrective action, effect on personnel safety and a discussion of the actual probability of failure, during an average operating cycle of 5,000 hours between overhauls will be provided. Each failure mode at the three and four levels will be separately discussed.

9.1 <u>Analysis of Drive System</u> - Refer to Figures 8 and 8(a) and the FMEA working papers regarding the Drive System.

9.1.1 <u>Motor (10.2)</u>

9.1.1.1 <u>Failure Mode 10.2.01 - No RPM</u> - This failure is generally caused by failure of the motor windings. The probability factor is extremely low, however, failure of the motor winding will cause the conveyor to be completely inoperative. There is no significant personnel safety hazard connected with failure of the motor. Corrective action is limited to replacing the motor or removing the motor and repairing the windings.

9.1.1.2 <u>Failure Mode 10.2.04 - Runs Rough</u>. This failure is generally caused by bad bearings. If allowed to continue the armature will eventually bind and fail the motor, causing loss of conveyor operation. No personnel safety hazard is involved and the actual probability of occurrence is extremely low. Corrective action is to remove and repair the motor immediately upon noting the condition.

9.1.1.3 Failure Mode 10.2.05 - On-Off Operation. This type of failure can be caused by partially shorted windings or by bad bearings which allow the armature to bind intermittently. Probability of failure is extremely low - no particular personnel safety hazard involved. Corrective action is limited to replacing the motor or removing the motor for repair.

9.1.2 Reducer (10.4)

9.1.2.1 Failure Mode 10.4.01 - No RPM. This failure mode can be the result of a broken worm gear, stripped worm or gear teeth, failed or frozen bearings, broken input shaft, broken or sheared keys, etc. These failures are mechanical and will result in conveyor stoppage. There is some personnel hazard involved if the non-overhauling properties of the Reducer are jeopardized. With proper lubrication and adequate inspection, the probability of this type of failure is low. Corrective action consists of removing and repairing the Reducer.

9.1.2.2 Failure Mode 10.4.04 - Load Trays Tilt - Drive Chains Out of Synchronization. This type of failure, wherein the load trays cock significantly increases the chance of tray jamming as the trays transition through the tail and head cam plates. With the single side control principle embodied in the new conveyor design, the probability of this type of failure has been significantly reduced due to the forgiving nature of the new design. However, tray cocking must be corrected whenever noted or a jam will eventually occur which, in addition to causing loss of conveyor operation, may do substantial damage to the cam plates, the track, package shields, trays and tray mounting devices. Little or no personnel hazard. Corrective action should be taken immediately and will usually consist of reworking keyways and replacing keys.

9.1.2.3 Failure Mode 10.4.02 - Runs Rough - Runs Noisy. This type of failure must be corrected when noted by replacing the bad bearings. If allowed to continue the bearing could fail resulting in damage to the Reducer Worm Gear and/or the Reducer Ring Gear; failure of the Reducer will cause loss of conveyor operation. Probability of failure is low but is enhanced by negligent maintenance practices. Little or no safety hazard to personnel except for possible loss of the non-overhauling feature of the Reducer.

9.1.2.4 Failure Mode 10.4.03 - Reducer Runs Hot - May Be Noisy - Input Shaft Hard to Turn. These symptoms indicate that the Reducer lubricant has been lost, is contaminated, has been improperly applied, etc. Damage may be significant when noted. The Reducer should be removed, opened, and checked for worm and gear wear, for bearing wear, for adequate seals. No personnel safety hazard unless ignored. This type of failure is preventable by good periodic maintenance and adequate inspection. The Contractor has noted instances of total Reducer neglect, which, unless disciplined, will lead to loss of conveyor operation and expensive Reducer damage.

9.1.3 Coupling (10.6)

9.1.3.1 Failure Mode 10.6.02 - Torsional Stress Failure. This type of failure is extremely remote unless the coupling material is seriously defective. Failure will result if tray cocking with associated incipient jams at the head or tail cam plates and incipient damage to conveyor parts and loss of conveyor operation. Little or no personnel hazard involved. Condition must be corrected immediately by coupling replacement.

9.1.3.2 Failure Mode 10.6.03 - Stress Failure of Key (s). The key stress is very low under full jam conditions which indicates that this type of failure is very remote. The same conditions apply as in paragraph 9.1.3.1. Immediate corrective action is necessary requiring replacement of the sheared or damaged keys. Careful inspection of the coupling and shaft keyways is necessary to assure that the replacement key will fit correctly.

9.1.3.3 Failure Mode 10.6.01 - Worn or Distorted Keys and/or Keyways. This type of failure usually preceeds failure mode 10.6.03 discussed in paragraph 9.1.3.2. Once wear is noted the key (s) should be replaced immediately and the keyways inspected for possible damage. As stated in the preceding paragraphs, worn or defective keys and/or keyway may allow the trays to cock increasing the propensity for tray jams as the trays translate through the cam plates.

9.1.4 Jack Shaft (10.7)

9.1.4.1 Failure Mode 10.7.02 - Torsional Stress Failure. This failure mode is highly improbable unless the jack shaft material is seriously defective. Should a jack shaft fail the results will depend on whether the Reducer is a double or single shaft output type. In the case of a double shaft output Reducer, failure of a jack shaft will cause loss of tray control on the failed side. Jamming will occur with associated damage and loss of conveyor operation. In the case of a single shaft output Reducer, failure of the jack shaft will cause total loss of conveyor operation. If loads are on the conveyor trays the conveyor will backtravel and jam. Hazard to personnel limited under most conditions however, the non-overhauling properties of the Reducer as well as the brake stopping torque will be ineffective and there would be no way to apply torque to the lifting chains until the failed shaft is replaced.

9.1.4.2 Failure Mode 10.7.03 - Coupling or Sprocket Key Stress Failure. Failure mode highly improbable since the keys are under low stress during jam conditions. Failure results are identical to those described under Failure Mode 10.7.02 (paragraph 9.1.4.1)

9.1.4.3 Failure Mode 10.7.01 - Worn or Distorted Keyways and/or Keys at Coupling and/or Sprockets. Worn or distorted keys and/or keyways may allow trays to cock with increased propensity to jam as the tray transition through the cam plates. This type of failure is highly improbable due to the low key stress. No particular hazard to personnel. Worn or distorted keys and/or keyway can be detected by inspection and must be repaired when noted.

9.1.5 Bearing (10.8)

9.1.5.1 Failure Mode 10.8.01 - Frozen Bearing. This type of failure is highly improbable since the pillow block bearings have been sized generously and since inspection and periodic maintenance procedures should detect and prevent occurrence. Failure will result in the loss of conveyor operation and will be immediately detectible. The motor is protected by the IOL and the thermal overload device. No personnel hazard since the conveyor will not move. Usual cause is corrosion contamination caused by negligent periodic maintenance. Bearing must be replaced - bearing repair is not recommended.

9.1.6 Drive Sprocket (10.9)

9.1.6.1 Failure Mode 10.9.02 - Sprocket Key Stress Failure. Failure highly improbable because of the low stress in the key. Should a key fail the results will be identical to those described under Coupling Failures (paragraphs 9.1.3.1, 9.1.3.2 and 9.1.3.3) and Jack Shaft Failures (paragraphs 9.1.4.1, 9.1.4.2 and 9.1.4.3).

9.1.6.2 Failure Mode 10.9.01 - Worn or Distorted Keyways and/or Keys at Sprockets. This type of failure produces the same results as that described under Jack Shaft's Failure Mode 10.7.01 (paragraph 9.1.4.3).

9.1.7 Drive Chain (10.10)

9.1.7.1 Failure Mode 10.10.01 - Stretched or Distorted Chain. Stretched chain can cause cocking of the carrier trays increasing the propensity of the trays to jam at the head and tail cam plates. This condition has been previously discussed. The chains operate at a factor of safety of not less than 10 to one, reducing the probability of this type of failure significantly. Stretched chain, when detected by inspection, should be replaced immediately. No particular personnel hazard.

9.2 Analysis of Conveyor Structure - Refer to Figures 9 and 9 (a) and the FMEA Working Paper Regarding the Conveyor Structure

9.2.1 Trunk (20.1)

9.2.1.1 (a) It is possible to introduce stresses into the trunk at installation if installation procedures are not followed by the installation mechanics.

The base plate, usually furnished by the shipbuilders must be flat and square across corners. W. ding must be done carefully to minimize the effects of weld shrinkage at the deck openings. There are no Level Three or Four catagories to consider.

(b) The Contractor is recommending that the trunk be welded to the deck collar using a "Z" configured filler weld plate to achieve flexibility. This design avoids the problem of weld shrinkage and minimizes shear loads at the deck openings.

9.3 Analysis of Operating System - Refer to Figures 10 and 10 (a) and the FMEA Working Papers Regarding the Operating System.

9.3.1 Head Cam Plate (30.1)

9.3.1.1 Failure Mode 30.1.02 - Tracks Broken. Jamming at the head cam plate historically has occurred as a result of tray cocking caused by worn keys, keyways, improper tensioning of the drive chains and packages left on trays. This cam plate design controls the tray transition from vertical to horizontal or horizontal to vertical from one side of cam plate -- never is control on both sides simultaneously as in previous designs. This results in a much more forgiving design capable of tolerating significant amounts of tray cocking without jamming. Thus the propensity for jamming at the head cam plate is greatly reduced. Broken tracks will cause jams and should be repaired immediately. Should a jam occur at the head cam plate, both left and right cam plates must be inspected and damage repaired before continuing operation. Personnel hazard is slight but resultant damage to trays and tray mounting devices could be extensive.

9.3.2 <u>Head Shaft (30.2)</u>

9.3.2.1 <u>Failure Mode 30.2.02 - Torsional Stress Failure</u>. The torsional stresses in the head shaft are well within design limits even under the worst jam conditions. Therefore, the probability of torsional failure is remote unless the material is faulty. A complete separation would dump all loads with associated resultant damage and possibility of loads striking operating personnel -- a head shaft separation has never been experienced. Proper inspection and checking all reasons for tray cocking should reveal incipient failure and the stressed shaft replaced.

9.3.2.2 <u>Failure Mode 30.2.03 - Sprocket Key Stress Failure</u>. Complete stress failure of the driven sprocket or carrier sprocket keys will allow the failed side to spin free creating tray cocking and imposing stresses on the holding side. Jams will occur at the head and tail cam plates. The key stresses are low; therefore, the probability of failure is remote. Personnel hazard is minimal. A completely failed key is immediately detectible and must be replaced.

9.3.2.3 <u>Failure Mode 30.2.01 - Worn or Distorted Keyways or Keys at the Driven Sprocket</u>. This type of failure results in tray cocking with associated possibility of jamming at the head and tail cam plates. Disciplined inspection to detect worn or distorted keys or keyways will enable replacement before cocking becomes intolerable for the cam plates to handle. Hazard to personnel is minimal. This condition results from repeated pounding of the keys and keyways usually caused by jams. Since the conveyor is protected against jams by a variety of safety devices (see Safety Devices No. 50) the possibility of jams has been significantly reduced.

9.3.3 Head Shaft Bearing (30.3)

9.3.3.1 Failure Mode 30.3.01 - Frozen Bearings. Failure results in loss of conveyor operation. Primary cause is corrosion contamination. Proper maintenance will do much to preclude failure occurring. No personnel hazard. Failed bearing must be removed and replaced.

9.3.4 Head Shaft Bearing Housing (30.4)

9.3.4.1 Failure Mode 30.4.01 - Housing Cracked or Broken

Failure can cause bearing to seize, stopping conveyor operation. Probability extremely remote and has never been experienced by Contractor. Minimal personnel hazard. Depending on type, location and severity of cracks or breaks, trays can cock with associated danger of jamming. Minor cracks are difficult to detect unless associated with symptoms noted herein. Faulty housing must be replaced.

9.3.5 Head Shaft Sprocket (30.5)

9.3.5.1 Failure Mode 30.5.02 - Sprocket Key Stress Failure

Same as Failure Mode 30.2.03 (see paragraph 9.3.2.2).

9.3.6 Carrier Chain (30.6)

9.3.6.1 Failure Mode 30.6.01 - Stretched or Distorted Carrier Chain. The new conveyor design is equipped with a chain tensioning device which pre-sets chain tension to a value selected to match the load capacity of the conveyor. In addition the factor of safety of the chain ranges from a low of 14 to one for the longest conveyor to 99 to one for the shortest conveyor. Accordingly, chain stretch is almost eliminated as a problem. Chain distortion or chain stretch could happen if one side of the system became disengaged as with a head shaft separation; or, should a bolt, nut, or other foreign material force the chain out of it's normal sprocket engagement. Most frequent symptom would be tray cocking, which if noted, should be checked immediately and corrective action taken. (Note - other causes of tray cocking have been noted and discussed in this Analysis Section).

9.3.7 Carrier Link (30.7)

9.3.7.1 Failure Mode 30.7.01 - Stretched or Distorted Link. The probability of this type of failure occurring is extremely remote due to the low stresses in the chain link under the most severe jam conditions. Failure would visualize as a cocked tray. Corrective action would be to replace the offending link; personnel hazard is minimal.

9.3.8 Chain Pin (30.8)

9.3.8.1 Failure Mode 30.8.01 - Disengagement of Chain Pin.

Paragraph 9.3.6.1 identifies the factor of safety applicable to the chain. The chain pin has been designed to keep stresses low in concert with the chain factor of safety. However, chain pins can disengage if not properly installed. This is a human factor and therefore, probability is impossible to determine. Should a chain pin totally disengage, the chain would separate, dropping all loads. Damage could be extensive; personnel could be struck by loads tumbling through doors. Checking chain pin engagement during periodic inspection and maintenance assures that this type of failure is avoided.

9.3.9 Carrier Shaft (30.9)

9.3.9.1 Failure Mode 30.9.01 - Excessive Torsional Stress Causing Shaft to be Bent or Broken. The combined torsional and bending stresses in the carrier shaft are within allowable limits under the worst jam conditions. Probability of torsional failure is low. Should failure occur, the trays would twist, exposing the conveyor to jams at the head and tail cam plates. Hazard to personnel is low; however, damage may be extensive to trays and tracks.

9.3.10 Guide Arm (30.10)

9.3.10.1 Failure Mode 30.10.01 - Key Shear Limit Exceeded. The key shear stress is low; therefore, the probability of this type of failure occurring is remote. Should the key fail the tray would be stabilized by the opposite side. However, during transition through the cam plates control of tray movement is passed from one side to the other and jams are likely. A sheared key can occur only during jam. When clearing a jam, the keys must be inspected and replaced if damaged. No hazard to personnel.

9.3.11 Guide Arm Cap (30.11)

9.3.11.1 Failure Mode 30.11.01 - Cap Shear Limit Exceeded. This type of failure will produce identical results to those identified under Failure Mode 30.10.01 (paragraph 9.3.10.1). Inspection of guide arm keys and caps after severe jam, i.e. fully loaded conveyor in strike-down operation is mandatory.

9.3.12 Front Track (30.15)

9.3.12.1 Failure Mode 30.15.02 - Tracks Broken. The front track will be treated as the track guiding the center-line mounted flanged cam follower; the rear track will be treated as the tray guiding the 45 degree arm mounted roller. Calculations show that the tray will pivot at the jam point under the force exerted by the chain pull. The worst possible jam condition will be a jam at a lower door coaming with a fully-loaded conveyor of 40 total trays, 20 loaded to 100 pounds each. Under these conditions, there is little or no load on the "front track". The resisting moment is provided by the 45 degree guide arm acting on the "rear track". The highest stress occurs therefore, in the single section "rear track". This stress exceeds the allowable stress of extruded aluminum by 16 percent (allowable stress 70 percent of tensile yield). However, the tensile yield is not exceeded and the design is safe and should not break or deform under the worst jam conditions. A minor design modification will bring the design into the "allowable stress range". Broken or deformed track must be replaced when noted. Broken or deformed track presents no personnel hazard but may lead to interrupted conveyor operation and serious damage should a guide roller escape track confinement.

9.3.13 Rear Track (30.16)

9.3.13.1 Failure Mode 30.16.02 - Tracks Broken. The analysis of paragraph 9.3.12.1 applies to this failure mode.

9.3.14 Tail Cam Plate (30.17)

9.3.14.1 Failure Mode 30.17.02 - Cam Tracks Broken. The analysis of paragraph 9.3.1.1 applies to this failure mode.

9.3.15 Tail Shaft Bearings (30.19)

9.3.15.1 Failure Mode 30.19.01 - Frozen Bearings. The analysis of paragraph 9.3.3.1 applies to this failure mode.

9.3.16 Head Driven Sprocket (30.21)

9.3.16.1 Failure Mode 30.21.02 - Sprocket Key Stress Failure. The analysis of paragraph 9.3.2.2 applies to this failure mode.

9.3.16.2 Failure Mode 30.21.01 - Worn or Distorted Keyways and/or Keys at Sprockets. The analysis of paragraph 9.3.2.3 applies to this failure mode.

9.4 Analysis of Control System - Refer to Figures 11 and 11 (a) and the FMEA Working Papers Regarding the Control System

9.4.1 Thermal Overload (40.1.2)

9.4.1.1 Failure Mode 40.1.2.1 - One or More Heater Elements Inoperative. In a three-phase circuit a thermal overload heater coil is inserted in each phase. One of the phases contains the current sensing coil for the instantaneous overload device. If a thermal overload heater coil fails in a phase not containing the IOL, the IOL will sense the increase in current and shut off power to the motor windings. If the thermal overload heater coil fails in the phase containing the IOL sensing coil, the IOL coil will not sense the increased current draw and the motor windings will overheat and eventually burn. The failure visualizes as refusal of the motor to start. Loss of a thermal overload heater coil means the conveyor will not run. Because of the damage which may occur if the operator continues to apply current to the motor under the conditions outlined above, the contractor recommends immediate corrective action should the motor not start when the circuit is energized. The contractor has not experienced a starter coil failure, therefore must conclude that the probability of failure is low. No personnel safety hazard invisioned even though failure could occur while operating with a fully-loaded conveyor since the non-overhauling properties of the Reducer will prevent run-away loads.

9.4.2 Instantaneous Overload (40.1.3)

9.4.2.1 Failure Mode 40.1.3.1 - Burned or Interrupted Coil. The relationship of the thermal overload heater coils to the instantaneous overload sensing coil is described in paragraph 9.4.1.1. Should the IOL sensing coil fail, the motor will single phase causing increased current draw to heat and activate the thermal overload. Conveyor operation is lost until the IOL coil is replaced. No personnel hazard -- probability of failure low -- the contractor has not experienced a loss of a properly sized IOL coil.

9.4.3 Instantaneous Overload By-pass Timer (40.1.4)

9.4.3.1 Failure Mode 40.1.4.1 - Burned or Interrupted Coil. This type of failure prevents motor operation because the initial surge of current at motor start will be sensed by the IOL sensing coil which will trip the IOL and de-activate the circuit. Conveyor may be operated using the Emergency Run Switch. Normal continuous conveyor operation is lost until the IOL coil is replaced. Probability of failure is low with a properly sized coil -- no personnel safety hazard.

9.4.3.2 Failure Mode 40.1.4.2 - Cracked or Broken Bellows. This type of failure has the same effect as Failure Mode 40.1.4.1 (paragraph 9.4.3.1). Essentially the IOL has no by-pass and, therefore, the IOL prevents motor operation. Conveyor operation is lost until the failure is repaired. No personnel safety involved.

9.4.3.3 Failure Mode 40.1.4.3 - Air Hole in Bellows Plugged.

This type of failure allows the IOL to by-pass current continuously effectively eliminating the IOL as a safety device. This failure is difficult to diagnose since the conveyor operates normally. However, should a jam occur or other circumstances arise which causes current surge, the IOL being inoperative, will not function and will allow current to continue to the motor with potential damage to the conveyor beyond that which would have occurred had the IOL been operative. Probability of this type of failure is low. No unusual personnel safety hazard.

9.4.4 Over-the-door Jam Sensing Relay (40.1.9)

9.4.4.1 Failure Mode 40.1.9.1 - Burned or Shorted Coil. De-activation of the over-the-door jam sensing relay prevents activation of the intermediate stations. The conveyor cannot be run except through the Emergency Run circuit until the relay is replaced. Low failure probability. No personnel hazard. (See para. 11.3)

9.4.5 Load/Unload Jam Sensing Relay (40.1.10)

9.4.5.1 Failure Mode 40.1.10.1 - Burned or Shorted Coil. De-activation of the load/unload jam sensing relay de-activates the "down" circuit. Conveyor will run in the strike-up mode only. Probability of failure low. No personnel hazard.

9.4.6 Power "On-Off" Selector Switch (40.2.1)

9.4.6.1 Failure Mode 40.2.1.1 - Burned or Worn Contacts. Failure of the selector switch to make contact results in no power to the control circuit. Conveyor does not run until the switch is replaced -- the emergency circuit is also inactive. Low probability - easy to diagnose - no personnel safety hazard.

9.4.7 <u>Three-position Speed Selector Switch (40.2.2)</u>

9.4.7.1 <u>Failure Mode 40.2.2.3 - Burned or Worn Contacts in all Positions</u>. Failure of the three-position switch to make contact in all positions results in no power to the motor -- conveyor does not run in normal or emergency run modes, until failure is corrected. No personnel safety hazard -- low probability of all three positions failing at same time.

9.4.8 <u>"Stop - Push, On - Pull" Switch (40.3.2)</u>

9.4.8.1 <u>Failure Mode 40.3.2.1 - Burned or Worn Contacts</u>. With this type of failure contact is not made when the switch is set in the "On - Pull" position. The conveyor will not run when the UP or DOWN push buttons are activated at any station until the failure is diagnosed and corrected. No safety hazard to personnel and very low probability of failure.

9.4.8.2 <u>Failure Mode 40.3.2.2 - Contacts Welded Together</u>. This is a more serious failure than Failure Mode 40.3.2.1 and results in continued conveyor operation when the switch is pushed to the STOP position. If allowed to run, the conveyor may jam with associated mechanical damage. The conveyor can be stopped by interrupting the circuit by utilizing the over-the-door jam sensing device or by turning off power at the Controller. Potential safety hazard if operator is surprized by the lack of conveyor response when "Push - Pull" switch depressed to STOP position and conveyor continues to run -- may cause operator to lose control of load in strike-up mode of conveyor operation. Probability of failure is low. Failure is immediately evident. "Push - Pull" switch should be replaced before operation is continued in spite of the fact that operation can be controlled by utilizing locally handy over-the-door safety device.

9.4.9 Up - Push Button (40.3.3)

9.4.9.1 Failure Mode - 40.3.3.1 - Burned or Worn Contacts. Circuit will not be energized when the Up - Push button is pressed in the UP direction. Conveyor operation limited to down direction only. Failure immediately evident. Failed switch must be replaced to operate in UP direction at the subject station. Little or no personnel hazard -- probability of failure low.

9.4.9.2 Failure Mode 40.3.3.2 - Contacts Welded Together. With this type of failure the conveyor will operate immediately when the control circuit is energized. May surprize operator and represents a serious failure which must be corrected immediately upon noting. Conveyor can be stopped by depressing "Push - Pull" switch or by utilizing the locally handy over-the-door jam sensing safety device. Probability of failure is low.

9.4.10 Down - Push Button (40.3.4)

9.4.10.1 Failure Mode 40.3.4.1 - Burned or Worn Contacts. Same type of failure as described under Failure Mode

40.3.3.1 (see paragraph 9.4.9.1).

9.4.10.2 Failure Mode 40.3.4.2 - Contacts Welded Together. Same type of failure as described under Failure Mode 40.3.3.2 (see paragraph 9.4.9.2).

9.5 Analysis of Safety Devices - Refer to Figures 12 and 12 (a) and the FMEA Working Papers Regarding the Safety Devices.

9.5.1 Bottom Overtravel Limit Switch (50.5)

9.5.1.1 Failure Mode 50.5.01 - Bottom Overtravel Limit Switch Locked Open. Failure in this mode means that the conveyor is inoperative in the down direction. Switch must be replaced. This type of failure is usually mechanical in nature and rare among commercial micro-switches. No hazard to personnel.

9.5.2 Failure Mode 50.6.01 - Loader/Unloader Interlock Switch is Locked Open. Identical to Failure Mode 50.5.01 (see para. 9.5.1.1).

9.5.3 Failure Mode 50.7.01 - Loader/Unloader Jam Sensing Switch is Locked Open. Identical to Failure Mode 50.5.01 (see paragraph 9.5.1.1).

9.5.4 Failure Mode 50.8.01 - Top Overtravel Switch Locked Open. Failure in this mode means that the conveyor is inoperative in the up direction. Switch must be replaced. This type of failure is usually mechanical in nature and rare among commercial micro-switches. No hazard to personnel.

9.5.5 Failure Mode 50.9.01 - Over-the-door Jam Sensing Switch Locked Open. This type of failure means that the conveyor is inoperative in both up and down directions. The failed switch must be located and replaced. This type of failure is usually mechanical in nature and rare among commercial micro-switches. No hazard to personnel.

9.6 Analysis of Load/Unload Device - Refer to Figures 13 and 13 (a) and to the FMEA Working Papers Regarding the Load/Unload Device

9.6.1 Mounting and Stowing Bracket R.H. (60.3).

9.6.1.1 Failure Mode 60.2.01 - Bent Bracket. Bent or distorted mounting brackets may make it difficult or impossible to place the load/unloader in the load, unload or stowed positions. Inability to seat the load/unloader in the unload or stowed positions properly will not allow the down circuitry to be completed, resulting in loss of conveyor operation in the down direction. Inability to seat the load/unloader in the load position properly may allow the down direction circuitry to remain completed allowing strike-down operation normally prevented by the load/unloader interlock switches. These failures are easily detectible allowing immediate corrective action. Probability is low -- personnel hazard is minimal.

9.6.2 Mounting and Stowing Bracket L.H. (60.4)

9.6.2.1 Failure Mode 60.3.01 - Bent Bracket. This failure mode is identical to Failure Mode 60.2.01 (see paragraph 9.6.1.1).

9.6.3 Platform Depress Mechanism L.H. (60.4)

9.6.3.1 Failure Mode 60.4.01 - Binding of Guide Shaft in Guide Plate Slide. If the guide shaft binds in the guide plate slide, the platform will not depress in the event of a jam. Protection against strike-down jam is lost at the subject station. Also, binding will make it impossible to position the load/unload device from the load position to the unload position, or, from the unload position to the load position dependant on which position the load/unload device was in when the binding occurred. Failure is easily detectible and must be corrected when noted. Failure probability is low. Personnel hazard minimal.

9.6.3.2 Failure Mode 60.4.02 - Binding in the Guide Plate Slide. This type of failure produces identical results as Failure Mode 60.4.01 (see paragraph 9.6.3.1).

9.6.3.3 Failure Mode 60.4.03 - Pins Work Out of Connecting Arms. If the pins work out of the connecting arms, the loader/unloader spring tension will be lost, making it impossible to position the load/unloader in the unload position. Conveyor operation in the down position will be lost. Failure is easily detectible and must be corrected immediately. Probability is low -- minimal personnel hazard.

9.6.3.4 Failure Mode 60.4.06 - Broken Spring. Failure of the load/unloader spring will make it impossible to place the load/unloader in the unload position resulting in loss of downward conveyor operation. Failure is easily detectible and must be corrected immediately. Probability is low. Personnel hazard is minimal.

9.6.4 Platform Depress Mechanism R.H. (60.5)

9.6.4.1 Failure Mode 60.5.01 - Binding of Guide Shaft in Guide Plate Slide. Failure identical to Failure Mode 60.4.01 (see paragraph 9.6.3.1).

9.6.4.2 Failure Mode 60.5.02 - Binding in Guide Plate Slide. Failure is identical to Failure Mode 60.4.02 (see paragraph 9.6.3.2).

9.6.4.3 Failure Mode 60.5.03 - Pins Work Out of Connecting Arms. Failure is identical to Failure Mode 60.4.03 (see paragraph 9.6.3.3).

9.6.4.4 Failure Mode 60.5.06 - Broken Spring. Failure is identical to Failure Mode 60.4.06 (see paragraph 9.6.3.4).

9.6.5 Cross Shaft (60.6)

9.6.5.1 Failure Mode 60.6.01 - Loose Coupling. Loose couplings would make it difficult or impossible to position the loader/unloader in the unload position. Conveyor operation in the strike-down mode would be lost. Loader/unloader may cock or tilt. Failure easily detectible and must be corrected when noted. Probability is low -- minimal personnel hazard.

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Motor
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		co
	SN	Description			Local Effect	End Effect	
10.2 Motor (1800, 1200 & 900 RPM)	10.2.01	No RPM	Burned Windings	High Current	Current Interrupt	Conveyor Inoperative	N
			Insulation Breakdown	High Current	Current Interrupt	Conveyor Inoperative	N
			Bearing Failure	High Current	Current Interrupt	Conveyor Inoperative	N
Powers Conveyor and allows a selection of 3-speeds; 8, 10.7 and 16 trays per minute	10.2.02	Will not run at 1200 RPM	1200 RPM Winding Burned Out	Speed Selection Limited to 1800 and 900	Same as Symptom	Conveyor Operation Limited to 16 and 8 trays per minute	N
	10.2.03	Will not run at 1800 and 900 RPM	1800 and 900 RPM Windings Burned Out	Speed selection limited to 1200 RPM	Same as Symptom	Conveyor Operation limited to 10.7 trays per minute	
	10.2.04	Runs Rough	Bad Bearings(s)	Vibration	Vibration Indicating Eminent Bearing Failure - Temperature Rise	Eminent Loss of Conveyor Operation	

(1) (2)

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ________ DATE: ________

...ses	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
...nding...	High Current	Current Interrupt	Conveyor Inoperative	None	4	1	Protected by IOL and Fuses
...n	High Current	Current Interrupt	Conveyor Inoperative	None	4	1	Protected by IOL and Fuses
	High Current	Current Interrupt	Conveyor Inoperative	None	4	1	Protected by IOL and Fuses
...urned	Speed Selection Limited to 1800 and 900	Same as Symptom	Conveyor Operation Limited to 16 and 8 trays per minute	None	1	1	Protected by IOL and Fuses
...900 ...ngs ...t	Speed selection limited to 1200 RPM	Same as Symptom	Conveyor Operation limited to 10.7 trays per minute	None	2	1	Protected by IOL and Fuses
...ngs(s	Vibration	Vibration Indicating Eminent Bearing Failure - Temperature Rise	Eminent Loss of Conveyor Operation	None	3	1	Thermal Overload

(12)

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 **VERTICAL CONVEYOR SYSTEM**
Indenture Level No. 2 Drive System
Indenture Level No. 3 Motor (Page -2-)
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pre
	SN	Description			Local Effect	End Effect	
10.2 Motor	10.2.05	On - Off Operation	Partially Shorted Windings	Motor Shuts Down - High Current	Temperature Rise	Intermittent Conveyor Operation	No
			Bad Bearing	Motor Shuts Down - High Current	Temperature Rise	Intermittent Conveyor Operation	No

(1) (2)

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
	Motor Shuts Down - High Current	Temperature Rise	Intermittent Conveyor Operation	None	3	1	Protected by IOL and Thermal Overload
	Motor Shuts Down - High Current	Temperature Rise	Intermittent Conveyor Operation	None	3	1	Protected by IOL and Thermal Overload

2

Form No 276 6

Indenture Level No. 1 **VERTICAL CONVEYOR SYSTEM**
Indenture Level No. 2 Drive System
Indenture Level No. 3 Torque Limiter
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		co
	SN	Description			Local Effect	End Effect	
10.3 Torque Limiter	10.3.01	Friction Disc worn, glazed fractured	- Improper adjustment -overheating -system overloaded	Conveyor does not reach full speed	Motor connection to system slips	Drive system is sluggish	
-The Torque Limiter provides conveyor protection -Is set at 110% to 115% of total load -It operates continuously -Prevents conveyor and motor damage should other devises fail	10.3.02	Bellwood spring is defective	-weak spring -corroded spring	Torque Limiter will not transmit load	Motor connection to system slips	Drive system is sluggish	
	10.3.03	Bearing failure	-fractured raceway -broken or missing rollers	Torque Limiter connection runs rough	Same as end effect	Drive system vibrates	
	10.3.04	Pressure nut loosens	-improper adjustment -set screws not locked tight	Conveyor does not reach full speed	Motor connection to system slips	Drive system sluggish	ght nut
	10.3.05	Key failure	Adjustment set to tight System over-loaded	Conveyor will not run	Same as end effect	Conveyor inoperative	

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ______________ DATE: ______________

...s	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...ng	Conveyor does not reach full speed	Motor connection to system slips	Drive system is sluggish	None	1	2	Disassemble Torque Limiter Replace friction disc (s) in Torque Limiter. Adjust per instruction in manual.
...ng	Torque Limiter will not transmit load	Motor connection to system slips	Drive system is sluggish	None	1	2	Disassemble Torque Limiter Replace Bellwood spring Adjust per instruction in manual
...ollers	Torque Limiter connection runs rough	Same as end effect	Drive system vibrates	None	2	1	Disassemble Torque Limiter Replace faulty bearing Adjust per instruction in manual
...s.	Conveyor does not reach full speed	Motor connection to system slips	Drive system sluggish	Tighten pressure nut	1	1	Adjust Torque Limiter in accordance with instructions in manual
... set ...er-	Conveyor will not run	Same as end effect	Conveyor inoperative	None	2	1	Remove Torque Limiter Rework Keways - replace key (s)

Form No 2766

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Reducer
Indenture Level No. 4
Drawing Commercial Park

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi[illegible] compe[illegible] prov[illegible]
	SN	Description			Local Effect	End Effect	
10.4 Reducer Reduces speed from 1800, 1200 and 900 RPM to 36, 24 and 18 RPM. Reducer is non-overhaul-ing to prevent reverse conveyor operation under load.	10.4.01	No output RPM	-broken worm -stripped worm teeth -broken gear -stripped gear teeth -failed or frozen bearing -broken in-put shaft -broken in-put shaft key	No output RPM	Same	Conveyor inoperative	Nor
	10.4.02	Runs rough - runs noisy	Bad bearing	Vibration, noise	Incipient loss of reducer	Incipient loss of conveyor operation	No
	10.4.03	Reducer runs hot - may be noisy - in-put shaft hard to turn	Loss or deterioration of lubricants -bad seals -cracked housing -no make-up lubricant added -wrong make-up lubricant added	-runs hot -visible evi-dence of lubricant on base plate -high motor current	Incipient loss of reducer	Incipient loss of conveyor operation	No

(2)

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
...rm ...ar ...ng ...ut ...ut	No output RPM	Same	Conveyor inoperative	None	4	1	Replace Reducer
	Vibration, noise	Incipient loss of reducer	Incipient loss of conveyor operation	None	3	1	Replace bearing
...n ...s ...up	-runs hot -visible evidence of lubricant on base plate -high motor current	Incipient loss of reducer	Incipient loss of conveyor operation	None	3	1	Service manual requires periodic inspection of oil level and specifies type and grade of make-up lubricant

(2)

Form No. 276-6

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Reducer (Page -2-)
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		co… p…
	SN	Description			Local Effect	End Effect	
10.4 Reducer	10.4.04	Load trays tilt-drive chains out of synchronization	-lubricant contaminated -one or both out-put shaft keys or keyways distorted or broken	Trays tilted -one side of tray driving the other	Incipient jam at head or bottom cam plates	Incipient loss of conveyor operation	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ______ DATE: ______

...ses	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
...t ...ted ...oth ...haft ...or	Trays tilted -one side of tray driving the other	Incipient jam at head or bottom cam plates	Incipient loss of conveyor operation	None	4	1	Service manual requires periodic check for condition of keys and keyways and check of drive chain synchronization.

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 10.5 Brake
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exist compa provi
	SN	Description			Local Effect	End Effect	
10.5 Brake Assures that conveyor will not reverse under load.	10.5.01	Coil Burnout	-weak insulation -wrong hookup	Brake will not disengage	IOL or thermal overload trips	Conveyor will not run	Non
	10.5.02	Engaging spring failure	-weak spring -corroded spring	Brake will not engage	Conveyor coasts to stop	Trays will not positio properly	Non
Assures that conveyor will stop and properly position trays at door openings.	10.5.03	Friction lining worn out	-improper gap adjustment -normal wear and tear	Brake will not engage properly	Conveyor coasts to a stop	Trays will not position properly	Non
Assures that conveyor will stop in the event of power failure.	10.5.04	Brake to reducer key failure	-weak material -wear and tear	Brake will not engage	Conveyor coasts to stop	Trays will not position properly	Nor
	10.5.05	Pressure plate mechanism failure	-weak material -wear and tear -corrosion	Brake will not engage	Conveyor coasts to stop	Trays will not positio properly	Nor
	10.5.06	Jerky stops Slow to stop Brake slips	-grease or oil on friction discs ard/or pressure plate -improper gap adjustment	Same as description	Same as description	Trays may not positio properly	Nor

FAILURE MODE AND EFFECT ANALYSIS REPORT

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Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
- p	Brake will not disengage	IOL or thermal overload trips	Conveyor will not run	None	2	1	Remove brake and replace coil.
	Brake will not engage	Conveyor coasts to stop	Trays will not position properly	None	1	1	Remove brake and replace spring
p r	Brake will not engage properly	Conveyor coasts to a stop	Trays will not position properly	None	1	1	Remove brake and replace friction lining.
al ar	Brake will not engage	Conveyor coasts to stop	Trays will not position properly	None	1	1	Remove brake - replace key - re-work keyways.
al ar	Brake will not engage	Conveyor coasts to stop	Trays will not position properly	None	1	1	Remove brake - repair or replace failed parts.
il r te p	Same as description	Same as description	Trays may not position properly	None	1	1	Remove brake - clean pressure plate - clean or replace friction discs.

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Coupling
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compo prov
	SN	Description			Local Effect	End Effect	
10.6 Coupling Connects Reducer Drive Shaft (s) to Jack Shafts	10.6.01	Worn or distorted keys and/or keyways	-repeated jams	Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	Non
	10.6.02	Torsional stress failure	-repeated jams -weak material	Trays tilt or cock	Jams at head or tail cams	Loss of conveyor operation	Maximum stress psi unde conditio
	10.6.03	Stress failure of key (s)	-repeated jams -weak material	Trays tilt or cock	Jams at head or tail cams	Loss of conveyor operation	Maximum stress psi unde conditio

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
ams	Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None	3	1	Replace couplings and keys or remove couplings and re-work keyways.
ial	Trays tilt or cock	Jams at head or tail cams	Loss of conveyor operation	Maximum torsional stress is 307 psi under jam conditions	4	1	Rep'ace coupling.
ial	Trays tilt or cock	Jams at head or tail cams	Loss of conveyor operation	Maximum key stress is 5112 psi under jam conditions	4	1	Replace keys.

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Jack Shaft (s)
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compens provid
	SN	Description			Local Effect	End Effect	
10.7 Jack Shaft (s) Connects the Reducer Drive Shafts to the Drive Sprockets	10.7.01	Worn or distorted key-ways and/or keys at coupling and/or sprockets	Repeated jams	Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None
	10.7.02	Torsional stress failure	-repeated jams -weak material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Shaft see maximum torsional of 4046 p jam condi
	10.7.03	Coupling or sprocket key stress failure	-repeated jams -weak material	Tilted or cocked trays	Jam at head or tail cams	Loss of conveyor operation	Keys see maximum of 8058 under ja conditio

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
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By ENGINEERING DEPT., KORNYLAK CORP.

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
s	Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None	3	1	Replace shafts and keys or remove shafts and re-work keyways.
ms al	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Shaft sees a maximum torsional stress of 4046 psi under jam conditions	4	1	Replace shaft.
al	Tilted or cocked trays	Jam at head or tail cams	Loss of conveyor operation	Keys see a maximum stress of 8058 psi under jam conditions	4	1	Replace keys.

Form No. 276-6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Bearing
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		co p
	SN	Description			Local Effect	End Effect	
10.8 Bearing Supports Jack Shaft at sprocket end	10.8.01	Frozen bearing	-lack of prope lubrication -contaminated -improper alignment	-high current -conveyor will not run	No jack shaft rotation	Conveyor inoperative	N
	10.8.02	Dynamic failure	-normal wear and tear -overload	-high current -erratic operation	Trays may rock	Incipient jams at cam track plates	Bearin sized life o hours. averag 140,00

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

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...es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...rope ...on ...ted	-high current -conveyor will not run	No jack shaft rotation	Conveyor inoperative	None	4	1	Service manual requires periodic inspection and lubrication of the pillow block bearings
...ar	-high current -erratic operation	Trays may rock	Incipient jams at cam track plates	Bearings are sized for a bio life of 28,000 hours and an average life of 140,000 hours	2	1	Replace pillow block bearing

Form No 776

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Drive Sprocket
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compensa provisi
	SN	Description			Local Effect	End Effect	
10.9 Drive Sprocket Connects the Jack Shaft or Reducer Output to the Head Shaft Sprocket	10.9.01	Worn or distorted key-ways and/or keys at sprockets	Repeated jams	Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None
	10.9.02	Sprocket key stress failure	-repeated jams -weak material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Keys see maximum s of 8058 p under jam condition

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
	Local Effect	End Effect				
Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None	3	1	Replace sprocket and keys. Remove sprocket and re-work keys and keyways.
Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Keys see a maximum stress of 8058 psi under jam conditions	4	1	Replace worn or distorted keys.

Form No. 276-6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Drive Chain
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		co[illegible]
	SN	Description			Local Effect	End Effect	
10.10 Drive Chain Transmits power from the Jack Shaft to the Head Shaft	10.10.01	Stretched or distorted chain	-repeated or excessive jams -faulty material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Chain[illegible] never [illegible] more [illegible] ultim[illegible] streng[illegible]

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED ________ DATE: ________

...ses	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...or jams	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Chains are never loaded to more than 10% of ultimate strength	4	1	This condition is highly improbable due to design. Replace faulty chain.

Form No. 276 6

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Drive System
Indenture Level No. 3 Chain Take-up
Indenture Level No. 4
Drawing

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exist compen provi
	SN	Description			Local Effect	End Effect	
10.11 Chain Take-up Removes slack from Drive Chains. Keeps both side of Carrier Chain alined, by equalizing tension.	10.11.01	Bearing failure	No lubrication -faulty material	Trays tilt or cock out of square	Incipient jams at head or tai cams	Incipient loss of conveyor operation	Non
	10.11.02	Faulty or poor adjustment	Repeated jams	Trays tilt or cock out of square	Incipient jams at head or tail cams	Incipient loss of conveyor operation	Non
	10.11.03	Broken adjusting screw -broken bracket -bent bracket	Repeated jams -mechanical damage	Trays tilt or cock out of square	Incipient jams at head or tail cams	Incipient loss of conveyor operation	Non

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
ion	Trays tilt or cock out of square	Incipient jams at head or tai cams	Incipient loss of conveyor operation	None	2	1	Replace take-up bearing. Repair take-up shaft.
ms	Trays tilt or cock out of square	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None	1	1	Correct adjustment. Synchronize and re-align conveyor
ms	Trays tilt or cock out of square	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None	2	1	Replace adjusting screw. Replace broken or bent bracket. Synchronize and re-align conveyor.

Form No 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Structure
Indenture Level No. 3 Trunk
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E[illegible] com[illegible] p[illegible]
	SN	Description			Local Effect	End Effect	
20.1 Trunk Provides support for conveyor mechanism Provides a watertight enclosure	20.1.01	Loss of water-tight integrity	-cracked welds -deterioration of door seal(s) -improper adjustment of door dogs -misalignment of foundation base -material corrosion	Will not hold water or air under pressure	Water can penetrate trunk from surrounding compartments -or- surrounding compartments from trunk	Same as local effect	N
	20.1.02	Trunk distortion	Shear loads at deck openings	-binding trays -rubbing -high current	-excess wear -noise	conveyor stalls	N
			Weld shrinkage at decks, base and trunk connections	-binding trays -rubbing -high current	-excess wear -noise	conveyor stalls	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

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By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
elds	Will not hold water or air under pressure	Water can penetrate trunk from surrounding compartments -or- surrounding compartments from trunk	Same as local effect	None	1	1	Find and repair cracked welds
tion al(s)					1	2	Replace door seals
of					1	2	Adjust dogs - replace if out of adjustability
ent ion					1	1	Installation problems - check drawings and service manual for proper installation procedures.
					1	2	Conveyor drains must be kept open - check trunk frequently for rust. Chip and repaint when necessary.
s	-binding trays -rubbing -high current	-excess wear -noise	conveyor stalls	None	1	1	Transmission of shear loads minimized by use of semi-flexible method of supporting conveyor at deck openings.
k - ks, runk s	-binding trays -rubbing -high current	-excess wear -noise	conveyor stalls	None	1	1	Exercise care during installation, especially in welding techniques

Form No. 276 6

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Head Cam Plate
Indenture Level No. 4
Drawing

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E com p
	SN	Description			Local Effect	End Effect	
30.1 Head Cam Plate The Head Cam Plate causes the carrier tray to make the horizontal to vertical transition as the carrier trays move front to back	30.01	Cam Tracks worn or distorted	Repeated jams	Conveyor runs rough	Same as symptom	-possible high current -possible nuisance IOL cut out -excessive slippage of torque limiter	Torqu can al shock come
	30.1.02	Cam tracks broken	Repeated jams	Conveyor jams at broken track	High current IOL cuts out	Pending loss of conveyor operation cam roll jams in broken cam track plate	Torqu slips

FAILURE MODE AND EFFECT ANALYSIS REPORT

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
ms	Conveyor runs rough	Same as symptom	-possible high current -possible nuisance IOL cut out -excessive slippage of torque limiter	Torque Limiter can absorb some shock or over-come roughness	2	2	Straighten and/or remove rough spots in cam track. Remove and replace faulty cam plate
ms	Conveyor jams at broken track	High current IOL cuts out	Pending loss of conveyor operation cam roll jams in broken cam track plate	Torque Limiter slips	4	2	Remove and repair cam plate or remove and replace faulty cam plate.

Form No. 276 6

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Head Shaft
Indenture Level No. 4
Drawing

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pr
	SN	Description			Local Effect	End Effect	
30.2 Head Shaft	30.2.01	Worn or distorted keyways or keys at the driven sprocket	Repeated jams	Trays tilt or cock	Incipient jams at head cam	Incipient loss of conveyor operation	No
The head shaft is the principal shaft which transfers the power to the tray system. The entire weight of the tray system and load are on this shaft	30.2.02	Torsional stress failure	Repeated jams faulty material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Shaft maximum nal str 5054 ps jam con
	30.2.03	Sprocket key stress failure	Repeated jams weak material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Keys s maximum of 9134 at jam conditi
	30.2.04	Bent head shaft	Extremely heavy jam	Carrier sprocket wobbles as it revolves	Same as symptom	-stretched chain -tray flexure	No (see r column

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
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[illegible]	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
jams	Trays tilt or cock	Incipient jams at head cam	Incipient loss of conveyor operation	None	3	1	Replace head shaft (s) and keys or remove shafts and rework keyways and keys
jams er-	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Shaft sees a maximum torsional stress of 5054 psi under jam conditions	4	1	Replace head shaft (s)
ams ial	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Keys see a maximum stress of 9134 psi at jam condition	4	1	Replace keys
	Carrier sprocket wobbles as it revolves	Same as symptom	-stretched chain -tray flexure	None (see remarks column)	2	1	Replace head shaft. Note: In the new design this shaft has been increased from 1.75" to 2.937" giving in excess of 4.7 times the previous strength.

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Head Shaft Bearing (s)
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi comp pro
	SN	Description			Local Effect	End Effect	
30.3 Head Shaft Bearing (s) Supports the head shaft at both the inboard and outboard end of the head shaft	30.3.01	Frozen bearings	Lack of proper lubrication -contamination -improper alignment	-high current -conveyor will not run	No head shaft rotation	Conveyor inoperative	No
	30.3.02	Dynamic failure	-normal wear and tear -overload	-high current -erratic operation	Trays may rock	Incipient jams at cam track plates	Bearing sized f 10 life 30,000 and an life of hours

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Contract No. N00024-72-C-5500
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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
er on	-high current -conveyor will not run	No head shaft rotation	Conveyor inoperative	None	4	1	Service manual requires periodic inspection and lubrication of head shaft bearings
	-high current -erratic operation	Trays may rock	Incipient jams at cam track plates	Bearings are sized for a B-10 life of 30,000 hours and an average life of 150,000 hours	2	1	Replace head shaft bearings

Form No. 2766

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Head Bearing Housing
Indenture Level No. 4
Drawing

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E com p
	SN	Description			Local Effect	End Effect	
30.4 Head Bearing Housing Houses the inboard and outboard shaft bearing	30.4.01	Head Bearing housing cracked or broken	Faulty casting or material	High current -conveyor will not run	-no head shaft rotation -trays tilt or cock	Incipient loss of conveyor operation	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

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...es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Rer :ks and Recommendations
		Local Effect	End Effect				
...ting ...1	High current -conveyor will not run	-no head shaft rotation -trays tilt or cock	Incipient loss of conveyor operation	None	4	1	Replace head shaft bearing housing. This contractor has never experienced a failure in this part after having produced vertical conveyor systems for over 20 years and over 400 units produced.

Form No 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Head Shaft Sprocket
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi comp pre
	SN	Description			Local Effect	End Effect	
30.5 Head Shaft Sprocket This item is the sprocket which becomes the driver and load support for the carrier trays	30.5.01	Worn head shaft sprocket	-misalignment -abnormal jams -abnormal loading	-polished teeth -ridges in teeth	Same as symptom	Rough conveyor operation	No
	30.5.02	Sprocket key stress failure	-repeated jams -weak or faulty materia	Tilted or cocked trays	Jam at head or tail cams	Loss of conveyor operation	Keys se maximum of 9134 jam con

FAILURE MODE AND EFFECT ANALYSIS REPORT

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By ENGINEERING DEPT., KORNYLAK CORP.

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
t ms	-polished teeth -ridges in teeth	Same as symptom	Rough conveyor operation	None	2	1	Replace head shaft sprocket
ia	Tilted or cocked trays	Jam at head or tail cams	Loss of conveyor operation	Keys see a maximum stress of 9134 psi at jam condition	4	1	Rework key seat and replace keys

Form No. 276 G

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Carrier Chain Section
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		con
	SN	Description			Local Effect	End Effect	
30.6 Carrier Chain Section The carrier chain section is the connecting link between each of the trays and the drive system.	30.6.01	Stretched or distorted carrier chain	-repeated or excessive jams -faulty material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Chain never more of ult streng

FAILURE MODE AND EFFECT ANALYSIS REPORT

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[illegible]es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
or jams	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Chains are never loaded to more than 10% of ultimate strength	4	1	Replace faulty chain. Note: This condition is highly improbable due to design loading of chain.

Form No 276 6

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Carrier Link
Indenture Level No. 4
Drawing

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E… com… pr…
	SN	Description			Local Effect	End Effect	
30.7 Carrier Link The carrier link provides the bearing and the linkage to connect the chain sections from tray to tray.	30.7.01	Stretched or distorted link	-repeated or excessive jams -faulty material	Tilted or cocked trays	Jams at head or tail cams	Impending loss of conveyor operation	No
	30.7.02	Worn sleeve in link	-faulty material -long use -lack of lubrication	-conveyor runs rough -conveyor is noisey	Same as end effect	Impending need to overhaul system	No

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
r ams	Tilted or cocked trays	Jams at head or tail cams	Impending loss of conveyor operation	None	3	1	Replace carrier link and associated chain parts.
	-conveyor runs rough -conveyor is noisey	Same as end effect	Impending need to overhaul system	None	2	1	Replace carrier link. Examine and replace any associated worn chain parts.

Form No. 2766

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Chain Pin
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		co...
	SN	Description			Local Effect	End Effect	
30.8 Chain Pin The chain pin connects the chain to the carrier link	30.8.01	Loss of cotter pin allowing chain pin to slide out of position	Cotter pin not bent sufficiently to keep chain pin engaged. -incomplete assembly or repair	Difficulty with or loss of proper engagement with sprocket	Bent side plates on chain or on carrier link	Impending loss of linkage in system	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ________ DATE: ________

...es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...n not ...ci- ...keep ...e ...r	Difficulty with or loss of proper engagement with sprocket	Bent side plates on chain or on carrier link	Impending loss of linkage in system	None	4	1	Replace associated damaged parts. Note: This can only occur if proper repair or assembly procedures are not followed.

(2)

Form No. 276 G

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Carrier Shaft
Indenture Level No. 4
Drawing 2-1026-P28

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pr
	SN	Description			Local Effect	End Effect	
30.9 Carrier Shaft	30.9.01	Excessive torsional stress causing shaft to be bent or broken	Jammed under full force of maximum reducer output	-visible misalignment of carrier tray -loose carrier tray	Jam may occur in tail or head cam plates or in vertical track	Probable loss of conveyor operation	Systen protec torque which protec by cau to sli

FAILURE MODE AND EFFECT ANALYSIS REPORT

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By ENGINEERING DEPT., KORNYLAK CORP.

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
er of tput	-visible misalignment of carrier tray -loose carrier tray	Jam may occur in tail or head cam plates or in vertical track	Probable loss of conveyor operation	System is protected by torque limiter which should protect conveyor by causing drives to slip	3	2	Replace carrier shaft and associated parts. May need to replace tray if damaged.

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Guide Arm and Guide Arm Cap
Indenture Level No. 4
Drawing 2-1026-P-27 and 2-1026 47F

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E[...] com[...] p[...]
	SN	Description			Local Effect	End Effect	
30.10 Guide Arm 30.11 Guide Arm Cap The guide arm and guide arm cap control the attitude of the tray from horizontal to vertical as the tray travels around the tray path	30.10.01 30.11.01	Key and cap shear limit exceeded	Jammed under a full force of maximum chain pull	Guide arm loose on shaft -guide arm cap distorted	Tray running out of horizontal position -tray loose in track guides	Incipient jams can occur in head or tail cam plate or in side guides	System protec[...] torque[...] which [...] cause [...] convey[...] cease [...]

FAILURE MODE AND EFFECT ANALYSIS
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...es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
...er a ... of ...ain	Guide arm loose on shaft -guide arm cap distorted	Tray running out of horizontal position -tray loose in track guides	Incipient jams can occur in head or tail cam plate or in side guides	System is protected torque limiter which should cause the conveyor to cease operation	4	1	Replace guide arm and guide arm cap and associated damaged parts.

Form No 276

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Cam Follower Flanged/Cam Follower
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compens provis
	SN	Description			Local Effect	End Effect	
30.12 Cam Follower Flanged 30.13 Cam Follower These cam followers guide the tray throug its manuevers on the tray pat	--	---	---	---	---	---	----

FAILURE MODE AND EFFECT ANALYSIS REPORT

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By ENGINEERING DEPT., KORNYLAK CORP.

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
	---	---	---	-----	--	--	There are no discernable means of failure evident by our calculations

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating Systems
Indenture Level No. 3 Carrier
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exis[illegible] compo[illegible] prov[illegible]
	SN	Description			Local Effect	End Effect	
30.14 Carrier	30.14.01	Excessive torsional stress	Jammed under full chain load at tip of tray finger	Visible bolt failure. Carrier tray not in normal position	Same as symptom	Carrier tray may jam in any position	Carrier [illegible] held in using sh[illegible] which sh[illegible] above IO[illegible] setting [illegible]

FAILURE MODE AND EFFECT ANALYSIS
REPORT

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Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

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...s	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...er ...n ...p ...nger	Visible bolt failure. Carrier tray not in normal position	Same as symptom	Carrier tray may jam in any position	Carrier tray held in position using shear bolts which shear above IOL setting	2	2	Drive out shear bolt stubs. Re-position carrier. Replace shear bolts with exact replacement. Reset IOL.

Form No 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Front Track and Rear Track
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E[illegible] com[illegible] pr[illegible]
	SN	Description			Local Effect	End Effect	
30.15 Front Track 30.16 Rear Track	30.15.01 30.16.01	Tracks worn or distorted	Repeated jams	Conveyor runs rough	Same as symptom	-possible high curren[illegible] -possible nuisance IOL cut out	Torque can a[illegible] same s[illegible] overco[illegible] roughn[illegible]
The track system controls the attitude of the tray from horizontal to vertical in the front to rear travel of the carrier	30.15.02 30.16.02	Tracks broken	Repeated jams	Conveyor jams at broken track	High current IOL cuts out	Pending loss of conveyor operation cam roll jams in broken track	Torque slips

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Contract No. N00024-72-C-5500
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By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ________ DATE: ________

[illegible]es	Symptums-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
ams	Conveyor runs rough	Same as symptom	-possible high current -possible nuisance IOL cut out	Torque Limiter can absorb same shock or overcome roughness	2	2	Straighten and/or remove rough spots in track. Remove and replace faulty track section
ams	Conveyor jams at broken track	High current IOL cuts out	Pending loss of conveyor operation cam roll jams in broken track	Torque Limiter slips	4	2	Remove and replace faulty track section

Form No 276 G

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Tail Cam Plate
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E com p
	SN	Description			Local Effect	End Effect	
30.17 Tail Cam Plate The Tail Cam Plate causes the carrier tray to make horizontal to vertical transition as the carrier trays move front to back	30.17.01	Cam tracks worn or distorted	Repeated jams	Conveyor runs rough	Same as symptom	-possible high current -possible nuisance TOL cut out -excessive slippage of Torque Limiter	Torque can ab shock come r
	30.17.02	Cam tracks broken	Repeated jams	Conveyor jams at broken track	High current TOL cuts out	Pending loss of conveyor operation cam roll jams in broken track	Torque slips

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Contract No. N00024-72-C-5500
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By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ______ DATE: ______

...es	Symptoms-detectability	Effect of Failure: Local Effect	Effect of Failure: End Effect	Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
...ams	Conveyor runs rough	Same as symptom	-possible high current -possible nuisance IOL cut out -excessive slippage of Torque Limiter	Torque Limiter can absorb some shock or overcome roughness	2	2	Straighten and/or remove rough spots in cam track. Remove and replace faulty cam plate
...ams	Conveyor jams at broken track	High current IOL cuts out	Pending loss of conveyor operation cam roll jams in broken track	Torque Limiter slips	4	2	Remove and repair cam plate or replace faulty cam plate

Form No. 2266

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Tail Shaft Sprocket
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex com pr
	SN	Description			Local Effect	End Effect	
30.18 Tail Shaft Sprocket This item becomes the main support and take-up for the carrier chain and guides the guide arms through the tail cam plate	30.18.01	Worn shaft sprocket	-misalignment -abnormal jams -abnormal loading	-polished teeth -ridges in teeth	Same as symptom	Rough conveyor operation	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

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s	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
ent	-polished teeth -ridges in teeth	Same as symptom	Rough conveyor operation	None	2	1	Replace tail shaft sprocket

Form No 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Tail Shaft Bearings (s)
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E com pr
	SN	Description			Local Effect	End Effect	
30.19 Tail Shaft Bearing (s) Supports the tail shaft (s) at both the inboard and outboard end of the tail shaft	30.19.01	Frozen bearing	-lack of prope lubrication -contamination -improper alignment	-high current -conveyor will not run	No tail sprocket rotation	Conveyor inoperative	N
	30.19.02	Dynamic failure	-normal wear and tear -overload	-high current -erratic operation	Trays may rock	Incipient jams at cam track plates	Bearin sized B-10 l 30,000 and an life o hours

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
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By ENGINEERING DEPT., KORNYLAK CORP.

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...s	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...rope ...n ...tion	-high current -conveyor will not run	No tail sprocket rotation	Conveyor inoperative	None	4	1	Service manual requires periodic inspection and lubrication of tail shaft bearings
...ar	-high current -erratic operation	Trays may rock	Incipient jams at cam track plates	Bearings are sized for a B-10 life of 30,000 hours and an average life of 150,000 hours	2	1	Replace head shaft bearings

Form No 276 G

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Chain Take-up
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E… com… pr…
	SN	Description			Local Effect	End Effect	
30.20 Chain Take-up	30.20.01	Loose lock bolts Loose jack screws Broken jack screw	-vibration -improper adjustment -repeated jams	-loose carrier chain -trays rock or tilt	Incipient jams at head or tail cam plates	-same as local effect -possible loss of conveyor operation	

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5580
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By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

...ses	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
n t	-loose carrier chain -trays rock or tilt	Incipient jams at head or tail cam plates	-same as local effect -possible loss of conveyor operation	None	2	1	Repair or replace broken parts - correct take-up adjustment

Form No 216 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Operating System
Indenture Level No. 3 Head Driven Sprocket
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi comp pre
	SN	Description			Local Effect	End Effect	
30.21 Head Driven Sprocket	30.21.01	Worn or distorted keyways and/or keys at sprockets	Repeated jams	Trays may tilt or cock	Incipient jams at head or tai cams	Incipient loss of conveyor operation	N
Connects the jack shaft or reducer output sprocket to the head shaft sprocket	30.21.02	Sprocket key stress failure	-repeated jams -weak material	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Keys s maximu under j conditi

FAILURE MODE AND EFFECT ANALYSIS REPORT

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By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

...ses	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
...ams	Trays may tilt or cock	Incipient jams at head or tail cams	Incipient loss of conveyor operation	None	3	1	Replace sprocket and keys. Remove sprocket and rework keys and keyways.
	Tilted or cocked trays	Jams at head or tail cams	Loss of conveyor operation	Keys see a maximum stress under jam conditions	4	1	Replace worn or distorted keys

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Reversing Starter
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exis compe provi
	SN	Description			Local Effect	End Effect	
40.1.1 Three-speed Reversing Starter The three-speed reversing starter is provided to give up/down directions and speed selection of 8, 10.7, or 16 trays per minute	40.1.1.1	Starter will not operate motor at 1800 RPM in either up or down direction	Burned out coi or burned or worn contacts on 1800 RPM starter	Conveyor will run okay in 900 and 1200 RPM mode but not in up or down at 1800 RPM	Conveyor does not run in one or more directions at 1800 RPM	Conveyor not fully operative in all speeds	Use spee which ar operativ
	40.1.1.2	Starter will no operate motor at 1200 RPM in one or both directions	Burned out coi or burned or worn contacts in 1200 RPM starter	Conveyor will run at 900 and 1800 RPM but not in up or down mode at 1200 RPM	Conveyor does not run in up or down mode at 1200 RPM	Conveyor not fully operative in all speeds	Use spee which ar operativ
	40.1.1.3	Starter will not operate motor at 900 RPM in one or both directions	Burned out coi or burned or worn contacts in 900 RPM starter	Conveyor will run at 1200 and 1800 RPM but not in up or down mode at 900 RPM	Conveyor does not run in up or down mode at 900 RPM	Conveyor not fully operative in all speeds	Use spee which ar operativ

FAILURE MODE AND EFFECT ANALYSIS REPORT

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
coi r ts	Conveyor will run okay in 900 and 1200 RPM mode but not in up or down at 1800 RPM	Conveyor does not run in one or more directions at 1800 RPM	Conveyor not fully operative in all speeds	Use speeds which are operative	1	1	Repair or replace coils or contacts or entire 1800 RPM starter
coi r ts	Conveyor will run at 900 and 1800 RPM but not in up or down mode at 1200 RPM	Conveyor does not run in up or down mode at 1200 RPM	Conveyor not fully operative in all speeds	Use speeds which are operative	1	1	Repair or replace coils or contacts or entire 1200 RPM starter
coi r ts	Conveyor will run at 1200 and 1800 RPM but not in up or down mode at 900 RPM	Conveyor does not run in up or down mode at 900 RPM	Conveyor not fully operative in all speeds	Use speeds which are operative	1	1	Repair or replace coils or contacts or entire 900 RPM starter

Form No 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Thermal Overload
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compen provi
	SN	Description			Local Effect	End Effect	
40.1.2 Thermal Overload Protects the motor against high current overloads in all of the three phases	40.1.2.1	One or more heater element inoperative	Burned out or interrupted heater coils	-motor may "single-phase" -motor may not run and may overheat	No motor RPM	Conveyor inoperative	Emergency switch
	40.1.2.2	One or more bi-metallic strips melted or broken	-high temperature due to high current -faulty or aged strip	-none under normal operation - frequent cutting-out of IOL if phase with IOL is lost and overloads -high current -motor over heats if lost phase not in same phase with IOL	No protection if phase without the IOL is lost	Motor may overheat if phase with lost thermal overload becomes overloaded -loss of conveyor if motor burns out	Non

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
or s	-motor may "single-phase" -motor may not run and may overheat	No motor RPM	Conveyor inoperative	Emergency run switch	4	1	Rest of thermal overloads would open - if failure not in IOL phase, IOL would open.
ra- t	-none under normal operation - frequent cutting-out of IOL if phase with IOL is lost and overloads -high current -motor over heats if lost phase not in same phase with IOL	No protection if phase without the IOL is lost	Motor may overheat if phase with lost thermal overload becomes overloaded -loss of conveyor if motor burns out	None	2	1	Perform checks of safety devices to assure operational capability per technical manual. Repair or replace faulty thermal overload controls

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Instant Overload Relay (IOL)
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi... compe... prov...
	SN	Description			Local Effect	End Effect	
40.1.3 Instant Overload Relay (IOL) This element protects the motor against a high current condition. It is set to cut out at 115% of normal load current.	40.1.3.1	-burned or interrupted coil	-faulty or aged material	-motor will single phase -motor will hum and may overheat -high current -motor may burn out windings not in IOL circuit	No motor RPM	Conveyor inoperative	Emergenc... switch

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
el	-motor will single phase -motor will hum and may overheat -high current -motor may burn out windings not in IOL circuit	No motor RPM	Conveyor inoperative	Emergency run switch	3	1	Thermal overloads would open due to single phasing of motor circuits. Repair or replace faulty instantaneous overload control.

Form No 276 6

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 IOL By-pass Timer
Drawing

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prov
	SN	Description			Local Effect	End Effect	
40.1.4 IOL By-pass Timer Timer allows three to five seconds for high starting motor current to reduce to a value that can be protected by IOL	40.1.4.1	Burned or interrupted coil	-solenoid sticking -worn linkage -insulation breakdown -burned contacts	Motor starts but stops when IOL kicks out	Motor will not run continuously	Conveyor inoperative	Emergenc switch
	40.1.4.2	Cracked or broken bellows	Worn or aged material	Motor starts but stops when IOL kicks out	Motor will not run continuously	Conveyor inoperative	Emergenc switch
	40.1.4.3	Air bleed hold has stopped up in bellows	-mechanical damage -dirty atmosphere	None under normal operation	No protection from IOL	Motor may overheat if system gets jammed or overloaded	Conveyo run but with IOI protecti

<u>FAILURE MODE AND EFFECT ANALYSIS REPORT</u>

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
ge	Motor starts but stops when IOL kicks out	Motor will not run continuously	Conveyor inoperative	Emergency run switch	3	1	Thermal overload will open due to high motor current. Repair or replace faulty IOL by-pass timer
tacts d	Motor starts but stops when IOL kicks out	Motor will not run continuously	Conveyor inoperative	Emergency run switch	3	1	Thermal overload will open due to high motor current. Repair or replace faulty IOL by-pass timer
	None under normal operation	No protection from IOL	Motor may overheat if system gets jammed or overloaded	Conveyor will run but not with IOL protection	3	1	Thermal overload will handle if high current. But mechanical damage may result before thermal overload can protect system.

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 110 Volt Transformer
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compen provi
	SN	Description			Local Effect	End Effect	
40.1.5 440V to 110V Transformer This 110V transformer supplies the power to operate all control circuits	40.1.5.1	Burned out or shorted winding	-faulty or overage material -mechanical damage	Relays and starters will not operate	No power to control part of system	Conveyor inoperative	None

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
Relays and starters will not operate	No power to control part of system	Conveyor inoperative	None	2	1	Rewind or replace faulty transformer.

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Speed Relays
Drawing Commercial

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compo prov
	SN	Description			Local Effect	End Effect	
40.1.6 First Speed Relay 40.1.7 Second Speed Relay 40.1.8 Third Speed Relay	40.1.6.1	Burned out coil	-faulty or overage material -mechanical damage to coil.	Speed selection limited to two remaining speed relays.	Same as end effect	Conveyor limited to two speeds	Use oper speeds remainin
These speed relays are provided so as to make proper selection of speeds from the Controller, they are interlocked in the circuit so that only one can operate at any one time.	40.1.6.2	Burned or welded contacts	-mechanical damage -overheating of contacts	Speed selection limited to one speed-same as locked in relay	Same as end effect	Conveyor limited to single speed	Use at o speed on

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	Speed selection limited to two remaining speed relays.	Same as end effect	Conveyor limited to two speeds	Use operable speeds remaining	1	1	Replace coil.
g	Speed selection limited to one speed-same as locked in relay	Same as end effect	Conveyor limited to single speed	Use at one speed only	1	1	Replace contacts or replace relay

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Over-the-door Jam Sensing Relay
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prov
	SN	Description			Local Effect	End Effect	
40.1.9 Over-the-door Jam Sensing Relay The over-the-door Jam Sensing Relay is provided to protect the conveyor if a package is out of position such that it would jam between the tray and the door in a strike-up mode.	40.1.9.1	Burned or shorted coil	-mechanical damage -faulty or overage material	No current to motor	Same as end effect	Conveyor inoperative	Non
	40.1.9.2	Contacts welded together	-high current -faulty material	None	None	Conveyor operative but does not have over-the-door protection	Torque will ta at 115% full lo torque

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	No current to motor	Same as end effect	Conveyor inoperative	None	3	1	Replace faulty coil or replace over-the-door Jam Sensing Relay
nt	None	None	Conveyor operative but does not have over-the-door protection	Torque Limiter will take over at 115% of full load torque	2	1	Replace Over-the-door Jam Sensing Relay

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Load/Unloader Interlock Jam Sensing Relay
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pro
	SN	Description			Local Effect	End Effect	
40.1.10 Load/Unloader Interlock Jam Sensing Relay This jam sensing relay is provided to protect the conveyor in the down direction if any platform is in the horizontal position	40.1.10.1	Burned or shorted coil	-mechanical damage -faulty or overage material	No current to motor in down mode	Same as end effect	Conveyor inoperative in down mode	No
	40.1.10.2	Contacts welded together	-high current -faulty material	None	None	Conveyor operative but does not have loader/unloader protection	Torque will ta at 115% load to

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elay

	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
er-	No current to motor in down mode	Same as end effect	Conveyor inoperative in down mode	None	3	1	Replace faulty coil or replace loader/unloader interlock jam sensing relay
nt	None	None	Conveyor operative but does not have loader/unloader protection	Torque Limiter will take over at 115% of full load torque	2	1	Replace loader/unloader interlock jam sensing relay

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Audio Signal Timer
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exis compe prov
	SN	Description			Local Effect	End Effect	
40.1.11 Audio Signal Timer This signal timer is provided to warn users that the conveyor is about to start. The conveyor starts only after the warning signal ceases	40.1.11.1	-burned or open coil -welded contacts	-faulty material -overage material -mechanical damage	-no warning sound -conveyor will not run	No current to motor	Conveyor inoperative	Non

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
-no warning sound -conveyor will not run	No current to motor	Conveyor inoperative	None	2	1	Repair or replace audio signal timer.

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FAILURE MODE AND EFFECT ANALYSIS
REP[illegible]

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller Station
Indenture Level No. 4 Power Off/On Selector Switch
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi[illegible] compe[illegible] prov[illegible]
	SN	Description			Local Effect	End Effect	
40.2.1 Power Off/On Selector Switch This switch is provided to turn on main control power.	40.2.1.1	-Burned contacts -Worn contacts	-Faulty material -overheating -overage material -over usage	-Red "Power On" light does not light. -No power to control circuit	No power to motor	Conveyor inoperative	Noi[illegible]

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	-Red "Power On" light does not light. -No power to control circuit	No power to motor	Conveyor inoperative	None	3	1	Replace power off/on switch.

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Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller Station
Indenture Level No. 4 Three-position Speed Selector Switch
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prov
	SN	Description			Local Effect	End Effect	
40.2.2 Three-position Speed Selector Switch This switch is provided for speed selection depending on skill of operating crew and the desired transfer rate.	40.2.2.1	Burned or worn contacts in one position	-Faulty material -Mechanical damage -Overheating -Overage material	One speed range is inoperable	Same as end effect	Conveyor operates in two speeds only.	Use ope speeds
	40.2.2.2	Burned or worn contacts in two positions	-Faulty material -Mechanical damage -Overheating -Overage material	Two speed ranges are inoperable	Same as end effect	Conveyor operates on one speed only	Use rem working
	40.2.2.3	Burned or worn contacts in all positions.	-Faulty material -Mechanical damage -Overheating -Overage material	All speeds are inoperable	No power to motor	Conveyor inoperative	No

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	One speed range is inoperable	Same as end effect	Conveyor operates in two speeds only.	Use operational speeds	2	1	Replace faulty speed selection switch.
	Two speed ranges are inoperable	Same as end effect	Conveyor operates on one speed only	Use remaining working speed.	2	1	Replace faulty speed selection switch.
	All speeds are inoperable	No power to motor	Conveyor inoperative	None	4	1	Replace faulty speed selection switch.

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Controller Station
Indenture Level No. 3 Power On Light "Red"
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compens previsi
	SN	Description			Local Effect	End Effect	
40.2.3 Power On Light "Red" This light indicates that the 110V and 440V pow:r are on to the conveyor	40.2.3.1	Burned out bulb. Loose wire. Faulty socket.	-Lack of maintenance -Excessive vibration -Overage material	Red light does not come on to indicate readiness	Same as end effect	Operating status is not known to operating personnel	Non

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
Red light does not come on to indicate readiness	Same as end effect	Operating status is not known to operating personnel	None	1	1	Check wiring - replace bulb or replace power-on red light.

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Controller
Indenture Level No. 4 Emergency Run Switch
Drawing ____________

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pre
	SN	Description			Local Effect	End Effect	
40.2.4 The emergency run switch is provided which overrides the overload controls	40.2.4.1	Emergency run switch locks in	Burned contacts	None	None	If conveyor should jam motor may burn out due to overheating without protection	Torque will ta if torq reaches normal
	40.2.4.2	Emergency run switch does not make contact	Mechanical damage	Detectable only if IOL or thermal overload cut out need to be bypassed	None	IOL and thermal overload control cannot be passed in case of emergency	No

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
...acts	None	None	If conveyor should jam motor may burn out due to overheating without protection	Torque Limiter will take over if torque reaches 115% of normal	2	1	Normal jam conditions would be detected by jam switches which would still be operable. This would have to be a jam of rare or unusual origin, before emergency run switch would be suspected
	Detectable only if IOL or thermal overload cut out need to be bypassed	None	IOL and thermal overload control cannot be passed in case of emergency	None	1	1	Remove cause of IOL and thermal overload cut out then replace emergency run switch

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Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Intermediate Station
Indenture Level No. 4 Green Power-On Light
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi[...] compe[...] prov[...]
	SN	Description			Local Effect	End Effect	
40.3.1 Green Power On Light This light is provided to advise operating crew at remote station that conveyor is ready to run at all other stations.	40.3.1.1	Burned out bulb Loose wire Faulty socket	-Lack of maintenance -Excessive vibration -Overage material	Light does not come on to indicate readiness	Same as end effect	Operational status is not known to crew	Crew me[...] call to[...] with ot[...] station[...] readine[...] equipme[...]

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
Light does not come on to indicate readiness	Same as end effect	Operational status is not known to crew	Crew member can call to or check with other stations for readiness of equipment.	1	1	Check wiring - replace bulb or replace power-on light.

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Intermediate Station
Indenture Level No. 4 Stop Push-On Pull (Red Light on Stop)
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exis[ting] compe[nsating] provi[sions]
	SN	Description			Local Effect	End Effect	
40.3.2 "Stop Push/On Pull" (Red Light on Stop) In the "Pull-On" Position this switch activates the conveyor circuit and allows up or down motion. In the "Push-Stop" position this switch deactivates the circuit and stops the conveyor.	40.3.2.1	Burned contacts Worn contacts	-Overheating -Faulty material -Overage material	Conveyor will not run when up or down switch are activated	Same as end effect	Conveyor inoperative (all stations must be set to on "on")	N
	40.3.2.2	Contacts welded together	-Overheating -Faulty material -Overage material	Conveyor always on in subject station (No red light in stop position)	Same as end effect	Conveyor operation cannot be stopped at subject station	N

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
Conveyor will not run when up or down switch are activated	Same as end effect	Conveyor inoperative (all stations must be set to on "on")	None	4	1	Verify switch condition. Replace "Stop Push-On Pull" button in faulty station.
Conveyor always on in subject station (No red light in stop position)	Same as end effect	Conveyor operation cannot be stopped at subject station	None	4	1	Replace "Stop Push-On Pull" button in faulty station.

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Control System
Indenture Level No. 3 Intermediate Station
Indenture Level No. 4 Up/Down Push Buttons
Drawing Commercial Part (s)

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi[illegible] compe[illegible] provi[illegible]
	SN	Description			Local Effect	End Effect	
40.3.3 40.3.4 "Up" Push Button "Down" Push Button	40.3.3.1 40.3.4.1	Burned or worn contacts	-Faulty material -Overheating -Overage material	Conveyor will not operate in one direction	Same as end effect	Conveyor operates in one direction only	No
This conveyor motion up or down push button is provided for selecting the direction of travel	40.3.3.2 40.3.4.2	Contacts welded together	-Overheating -Faulty material	Conveyor locked in to one run direction	Same as end effect	Conveyor operates in one direction as soon as "[illegible] Full" switch is activated	No

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	Conveyor will not operate in one direction	Same as end effect	Conveyor operates in one direction only	None	3	1	Replace faulty "Up" or "Down" push button
	Conveyor locked in to one run direction	Same as end effect	Conveyor operates in one direction as soon as "On Pull" switch is activated	None	3	1	Replace faulty "Up" or "Down" push button

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Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Instantaneous Overload (IOL)
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prov
	SN	Description			Local Effect	End Effect	
50.1 Instantaneous Overload (IOL) See Remarks Column	---	---	---	---	---	---	---

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
	---	---	---	----	--	--	This item is analyzed as part of the control system as element number 40.1.3

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Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Thermal Overload
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe pre
	SN	Description			Local Effect	End Effect	
50.2 Thermal Overload See Remarks Column	---	---	---	---	---	---	---

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ns	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
	---	---	---	-----	--	--	This item is analyzed as part of the control system -- element number 40.1.2

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Audio Signal
Indenture Level No. 4 Commercial Part
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exis[illegible] compe[illegible] provi[illegible]
	SN	Description			Local Effect	End Effect	
50.3 Audio Signal The audio signal sounds off at each level to warn personnel that conveyor is about to start. This signal operates two to three seconds before conveyor motion starts	50.3.01	Sounding coil shorted out	-electrical damage -high current	Low volume or no sound	Same as end effect	Conveyor operative however it has no start-up signal	Non
	50.3.02	Sounding coil open	Electrical damage	No sound	Same as end effect	Conveyor operative however it has no start-up signal	Non
	50.3.03	Diaphram ruptured	-mechanical damage -faulty or overage material	Distorted or inaudible sound	Same as end effect	Conveyor operative but has no clear start-up signal	Non

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
nt	Low volume or no sound	Same as end effect	Conveyor operative however it has no start-up signal	None	1	1	Repair or replace horn
	No sound	Same as end effect	Conveyor operative however it has no start-up signal	None	1	1	Repair or replace horn
	Distorted or inaudible sound	Same as end effect	Conveyor operative but has no clear start-up signal	None	1	1	Repair or replace horn

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Brake
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prev
	SN	Description			Local Effect	End Effect	
50.4 Brake See Remarks Column	---	---	---	---	---	---	--

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	---	---	---	----	--	--	This item is analyzed as part of the drive system -- element number 10.5

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FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Bottom Overtravel Limit Switch
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi comp pre
	SN	Description			Local Effect	End Effect	
50.5 Bottom Over-Travel Limit Switch	50.5.01	Bottom over-travel limit switch locked open	-bottom limit switch damaged -poor contacts	Conveyor inoperative in down travel	Same as symptom	------	No
This bottom overtravel limit switch senses and prevents packages from passing through, it operates on strike down only	50.5.02	Bottom limit switch locked closed	-bottom limit switch damaged -welded contacts -locked actuator -damaged contact spring	Bottom limit switch is not capable of detecting and stopping conveyor in down travel even with a jammed package	Package may jam without protection	Conveyor operative in down travel but the poten-tial to jam is increased significantly	Torque will t if a j create torque of ful torque

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
nit acts	Conveyor inoperative in down travel	Same as symptom	------	None	4	1	Correct cause of problem at bottom of conveyor. Replace bottom over-travel limit switch
nit ring	Bottom limit switch is not capable of detecting and stopping conveyor in down travel even with a jammed package	Package may jam without protection	Conveyor operative in down travel but the potential to jam is increased significantly	Torque Limiter will take over if a jam creates a torque of 115% of full load torque	2	1	Remove cause of limit switch damage. Replace bottom over-travel switch.

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Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Loader/Unloader Interlock
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe pre
	SN	Description			Local Effect	End Effect	
50.6 Loader/ Unloader Interlock	50.6.01	Loader/Unloader interlock switch is locked open	-limit switch damaged -poor contacts	Conveyor is inoperative in down travel	---	Same as symptom	No
The Loader/ Unloader inter-lock prevents strike down operation should the Loader/ Unloader be in horizontal position instead of the tilted unload position-operates during strike down.	50.6.02	Loader/Unloader interlock switch is locked in closed position	-limit switch damaged -welded contacts -locked actuator -damaged contact spring	Loader/Unloader switch is not capable of detecting that Loader/ Unloader is in horizontal position and cannot prevent down travel.	Package may jam without protection	Conveyor operative however the possibility of a jam in down travel is significan-tly incre-ased.	Torque will ta if jam a torqu 115% of load to

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
ch cts	Conveyor is inoperative in down travel	---	Same as symptom	None	4	1	Correct cause of problem at Loader/Unloader interlock. Replace Loader/Unloader interlock switch.
ch ing	Loader/Unloader switch is not capable of detecting that Loader/Unloader is in horizontal position and cannot prevent down travel.	Package may jam without protection	Conveyor operative however the possibility of a jam in down travel is significantly increased.	Torque Limiter will take over if jam creates a torque of 115% of full load torque.	2	1	Remove cause of limit switch damage. Replace Loader/Unloader interlock switch

Form No. 276-6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Loader/Unloader Jam Sensing Switch
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prov
	SN	Description			Local Effect	End Effect	
50.7 Loader/ Unloader Jam Sensing Switch	50.7.01	Loader/Unloader Jam Sensing switch is locked open	-limit switch damaged -bad contacts	Conveyor is inoperative in down travel	---	Same as symptom	Non
This Loader/ Unloader Jam Sensing Switch stops the conveyor should a down-coming tray strike a package not completely ejected after the package has depressed the Loader/Unloader a pre-set distance	50.7.02	Loader/Unloader Jam Sensing Switch is locked closed	-limit switch damaged -welded contact -locked actuator -damaged contact spring	Loader/ Unloader jam sensing switch is not capable of detecting a package not completely ejected from Loader/ Unloader	Package may jam without protection	Conveyor operative but the propensity to jam is increased significantly	Torque will ta if jam a torqu 115% of load to

FAILURE MODE AND EFFECT ANALYSIS REPORT

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es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
tch cts	Conveyor is inoperative in down travel	---	Same as symptom	None	4	1	Correct cause of problem at Loader/Unloader jam sensing switch. Replace Loader/Unloader jam sensing switch
tch ntac ring	Loader/Unloader jam sensing switch is not capable of detecting a package not completely ejected from Loader/Unloader	Package may jam without protection	Conveyor operative but the propensity to jam is increased significantly	Torque Limiter will take over if jam creates a torque of 115% of full load torque	2	1	Remove cause of Loader/Unloader Jam Sensing Switch damage. Replace Loader/Unloader Jam Sensing Switch.

Form No 2766

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Top Overtravel Limit Switch
Indenture Level No. 4
Drawing

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pro
	SN	Description			Local Effect	End Effect	
50.8 Top Overtravel Limit Switch	50.8.01	Top Overtravel Limit Switch locked open	-top limit switch damaged -poor contacts	Conveyor inoperative in "up" travel	Same as symptom	----	No
This top overtravel limit switch prevents packages from passing through and jamming at the top of the conveyor. Operates on strike up only.	50.8.02	Top Overtravel Limit Switch locked closed	-top limit switch damaged -welded contacts -locked actuator -damaged contact spring	Top overtravel limit switch is not capable of detecting and stopping conveyor in "up" travel even with a package in the jam position	Package may jam without protection	Conveyor operative but the propensity to jam is increased significantly	Torque will t if jam a torqu 115% of load to

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

s	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
cts	Conveyor inoperative in "up" travel	Same as symptom	----	None	4	1	Correct cause of problem at top of conveyor. Replace top overtravel limit switch.
ring	Top overtravel limit switch is not capable of detecting and stopping conveyor in "up" travel even with a package in the jam position	Package may jam without protection	Conveyor operative but the propensity to jam is increased significantly	Torque Limiter will take over if jam creates a torque of 115% of full load torque	2	1	Correct cause of problem. Replace top overtravel limit switch.

Form No 2766

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Over-the-door Jam Sensing Switch
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi comp pro
	SN	Description			Local Effect	End Effect	
50.9 Over-the-door Jam Sensing Switch	50.9.01	Over-the-door jam sensing switch locked open	-door jam switch damaged -poor contacts	Conveyor inoperative in both directions	----	Same as symptom	No
This over-the-door jam sensing switch stops the conveyor if activated by a mislocated package -- prevents a jam between the tray and the upper door coaming.	50.9.02	Over-the-door jam sensing switch locked closed	-door jam switch damaged -welded contact -locked actuator -damaged contact spring	Switch is not capable of detecting and stopping conveyor in up or down travel with a jammed package	Package may jam without protection	Conveyor operative but the propensity to jam is increased significantly	Torque will ta if a ja a torqu 115% of load to

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

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	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
...cts	Conveyor inoperative in both directions	----	Same as symptom	None	4	1	Correct cause of problem. Replace over-the-door jam sensing switch.
...aged ...tac ...ing	Switch is not capable of detecting and stopping conveyor in up or down travel with a jammed package	Package may jam without protection	Conveyor operative but the propensity to jam is increased significantly	Torque Limiter will take over if a jam creates a torque of 115% of full load torque.	2	1	Remove cause of limit switch damage. Replace over-the-door jam sensing limit switch.

Form No. 276-6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Safety Devices
Indenture Level No. 3 Torque Limiter
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi compen provi
	SN	Description			Local Effect	End Effect	
50.10 Torque Limiter See Remarks Column	--	---	----	---	--	--	----

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ______ DATE: ______

	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	---	--	--	----	--	--	This item analyzed as part of the drive system as element number 10.3

Form No. 2766

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices
Indenture Level No. 3 Platform
Indenture Level No. 4
Drawing 2-1026-51F

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Ex comp pro
	SN	Description			Local Effect	End Effect	
60.1 Platform The platform is the device which is used to position the loads for pick off in the up mode or extract loads in the down mode	60.1.01	Platform is not readily positioned between brackets	Improper clearance between brackets	Difficult to move from stowed position to load position and/ or unload	Difficult to put into use	Nuisance factor	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED. ______ DATE: ______

Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
Difficult to move from stowed position to load position and/ or unload	Difficult to put into use	Nuisance factor	None	2	1	Replace shim washer to get proper clearance

Form No. 276-6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices
Indenture Level No. 3 Mounting and Stowing Bracket R.H. and L.H.
Indenture Level No. 4
Drawing 2-1026-52F/2-1026-53F

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi... compens... provisi...
	SN	Description			Local Effect	End Effect	
60.2 Mounting and Stowing Bracket R.H. 60.3 Mounting and Stowing Bracket L.H. Supports the platform in various positions	60.2.01 60.3.01	Bent bracket	External damage	Impossible or difficult to position platform in load and/or unload positions	Limited direction travel	No down travel if not able to place in unload position	Non...

FAILURE MODE AND EFFECT ANALYSIS REPORT

H.

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ______ DATE: ______

Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
	Local Effect	End Effect				
Impossible or difficult to position platform in load and/or unload positions	Limited direction travel	No down travel if not able to place in unload position	None	4	1	Remove pivot studs. Remove platform straighten brackets. Re-assemble platfoım.

Form No. 276 6

(2)

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices
Indenture Level No. 3 Platform Depress Mechanism R.H. and L.H.
Indenture Level No 4
Drawing 2-1026-P10F

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Existi[ng] compens[ating] provisi[ons]
	SN	Description			Local Effect	End Effect	
60.4 Platform Depress Mechanism L.H.	60.4.01 60.5.01	Binding of guide shaft in guide plate slide	Wear	Platform finger cannot be depressed	Platform will not depress to open down travel circuit	With down travel circuit still engaged there is no jam protection in down mode	Non
60.5 Platform Depress Mechanism R.H. With platform tilted about 30 degrees from horizontal the load/unload [me]chanism is designed to sense a down-coming jam. By depressing the tip of the platform finger this releases an over-the-center latch de-activating the jam sensing switch and stopping the conveyor	60.4.02 60.5.01	Binding in guide plate slide	Wear	Platform finger cannot be depressed	Platform will not depress to open down travel circuit	With down travel circuit still engaged there is no jam protection in down mode	No
	60.4.03 60.5.03	Pins work out of connecting arms	Wear	Loss of spring pressure	Cannot position unloader	No down travel	N
	60.4.04 60.5.04	Pivot block holes are oversize	Wear	Sensing travel of platform is increased	Slower reaction due to the increased sensing movement required	Nuisance shut down for adjustment	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00124-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

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Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
Platform finger cannot be depressed	Platform will not depress to open down travel circuit	With down travel circuit still engaged there is no jam protection in down mode	None	4	1	Dis-assemble guides. Replace worn guide shaft.
Platform finger cannot be depressed	Platform will not depress to open down travel circuit	With down travel circuit still engaged there is no jam protection in down mode	None	4	1	Remove guides - replace worn [illegible]de guides
Loss of spring pressure	Cannot position unloader	No down travel	None	4	1	Replace pins in connecting arm - replace connecting arm
Sensing travel of platform is increased	Slower reaction due to the increased sensing movement required	Nuisance shut down for adjustment	None	1	1	Adjust bolt on shifter arm

- continued -

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices (page -2-)
Indenture Level No. 3 Platform Depress Mechanism R.H. and L.H. (cont'd)
Indenture Level No. 4
Drawing 2-1026-P10F

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exi compe prov
	SN	Description			Local Effect	End Effect	
				- continued -			
	60.4.05 60.5.05	Worn pivot arm bushing	Wear	Slight loss of spring pressure	Increased sensitivity to smaller loads	Nuisance shut down for adjustment	N
	60.4.06 60.5.06	Broken spring	-fatigue -faulty material	Unable to raise platform from load to unload position	If platform is not in unload position there can be no down travel	No down travel	N

FAILURE MODE AND EFFECT ANALYSIS REPORT

H. (cont'd)

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
	Local Effect	End Effect				
- continued -						
Slight loss of spring pressure	Increased sensitivity to smaller loads	Nuisance shut down for adjustment	None	1	1	Adjust spring pressure
Unable to raise platform from load to unload position	If platform is not in unload position there can be no down travel	No down travel	None	4	1	Replace broken spring. Adjust linkage and spring pressure to suit

Form No. 276-6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices
Indenture Level No. 3 Cross Shaft
Indenture Level No. 4
Drawing 2-1026-54F

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		E[illegible] comp[illegible] pr[illegible]
	SN	Description			Local Effect	End Effect	
60.6 Cross Shaft Links two sides together to maintain parallelism. Gives platform support on both sides	60.6.01	Loose coupling	Vibration	-coupling visably loose -looseness of stub shaft -loss of spring pressure	Guides will not lock into unload position	-platform would cock or jam -would not reach unload position -no down mode operation	N[illegible]

(1)

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

...es	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
	-coupling visably loose -looseness of stub shaft -loss of spring pressure	Guides will not lock into unload position	-platform would cock or jam -would not reach unload position -no down mode operation	None	4	1	Place platform in load position. Re-position stub shaft and levels. Tighten coupling.

Form No. 276-6

Indenture Level No 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices
Indenture Level No. 3 Interlock Micro-Switch
Indenture Level No. 4
Drawing Commercial Part

FAILURE MODE AND EFFECT ANALYSIS REPORT

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		Exist compen provi
	SN	Description			Local Effect	End Effect	
60.7 Interlock Micro-Switch See Remarks Column	--	---	---	---	---	---	--

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ______ DATE: ______

	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure prob-ability	Remarks and Recommendations
		Local Effect	End Effect				
	---	---	---	---	--	--	This item analyzed as part of the safety devices as Element Number 50.6

Form No. 276 6

FAILURE MODE AND EFFECT ANALYSIS REPORT

Indenture Level No. 1 VERTICAL CONVEYOR SYSTEM
Indenture Level No. 2 Load/Unload Devices
Indenture Level No. 3 Jam Sensing Micro-Switch
Indenture Level No. 4
Drawing Commercial Part

Output specification functional description	Failure Mode		Possible causes	Symptoms-detectability	Effect of Failure		En comp pr
	SN	Description			Local Effect	End Effect	
60.8 Jam Sensing Micro-Switch See Remarks Column	--	---	---	---	--	--	

(T)

FAILURE MODE AND EFFECT ANALYSIS REPORT

Contract No. N00024-72-C-5500
Organization KORNYLAK CORPORATION
By ENGINEERING DEPT., KORNYLAK CORP.

APPROVED: ____________ DATE: ____________

...s	Symptoms-detectability	Effect of Failure		Existing compensating provision	Level of Severity	Failure probability	Remarks and Recommendations
		Local Effect	End Effect				
	---	--	--	---	--	--	This item analyzed as part of the s.fety devices as Element Number 50.7

Form No 2166

11. Conclusions and Recommendations

11.1 Figure 14 provides an overview of the number of potential failures in each probability and severity block and the percentage of such failures compared to the total number of potential failures. There are no failures with a probability greater than two -- all failures with a severity of three or four were covered individually in the analysis section of this report (See Section 9).

11.2 Any loss of conveyor operation was assigned a severity factor of three or four. As a result, potential failure of ancillary equipment such as micro-switches, push buttons and elements of the Controller and Drive System were included and contributed significantly to the numbers shown in the three or above severity level blocks. Such equipment is not related to the conveyor structure or the conveyor's operating componentry. If potential failure of ancillary equipment is eliminated from consideration, the total number of potential failures from structural and operating system components only reduces the number of potential failures in the three or above catagories from an overall total of 67 to a total of 30.

11.3 During the analysis it was determined that the "Emergency Run" by-pass circuitry did not enable the conveyor to be run so as to clear a jam sensed and stopped by the "over-the-door" jam sensing safety device. The other safety devices are, in a sense, self-clearing. For instance: should a package jam during strike-down on the load/unload device, the platform will collapse and stop the conveyor. However, the conveyor can be operated in the up direction and the jam cleared. The same is true for the bottom and top jam safety devices. By making a simple change in the wiring location of the over-the-door jam sensing relay, relative to the wiring of the Emergency Run by-pass circuit, the Emergency Run circuit could be used to by-pass the over-the-door cut-out circuit and enable a jam at a top-of-the-door coaming to be cleared. This change will be incorporated by the Contractor unless otherwise instructed by Naval Ships Command.

11.4 During the calculations which preceeded the analysis of the Operating System, it was determined that the "narrow track section" represented the weakest member of the Operating System componentry. The Contractor will revise the design of the track to strengthen this section.

11.5 In concert with Paragraph 3.4.(e) of Specification Ships-C-5552 reading, in part, "...in the event of jamming, easily replaceable components shall yield or be damaged.", the Contractor is considering a series of shear bolts, sized to the anticipated load carrying capability of the family of various lengths of conveyors, be incorporated to fasten the carrier tray to the carrier arm and chain link. The Contractor forsees a potential problem should a jam occur which would shear such bolts and allow the tray to pass through the jam, <u>if</u>, the instantaneous overload <u>does not</u> trip and stop the conveyor. Not stopping the conveyor with a tray out of position could create serious damage when the tray transitions through the head and tail cam plates. The problem is one of sensitivity of the IOL sensing coil and is particularly acute with smaller length conveyors. Should shear bolts be adopted, the Contractor feels a re-set device must be added to the IOL circuitry to prevent re-starting the conveyor without first determining and correcting the cause of the IOL cut-out. The Contractor recommends a study of the sizes of shear bolts needed and the relative sensitivity of the IOL sensing coils be made prior to incorporation of the shear bolt design, although adaptation of this concept presents an ideal solution to the requirements of Paragraph 3.4(e) of Ships-C-5552.

11.6 The Contractor recommends that the mounting and stowage brackets of the Loader/Unloader be bolted to the conveyor rather than welded as presently shown. Bolt-on brackets will enable easier removal and maintenance of the rather complex load/unload device.

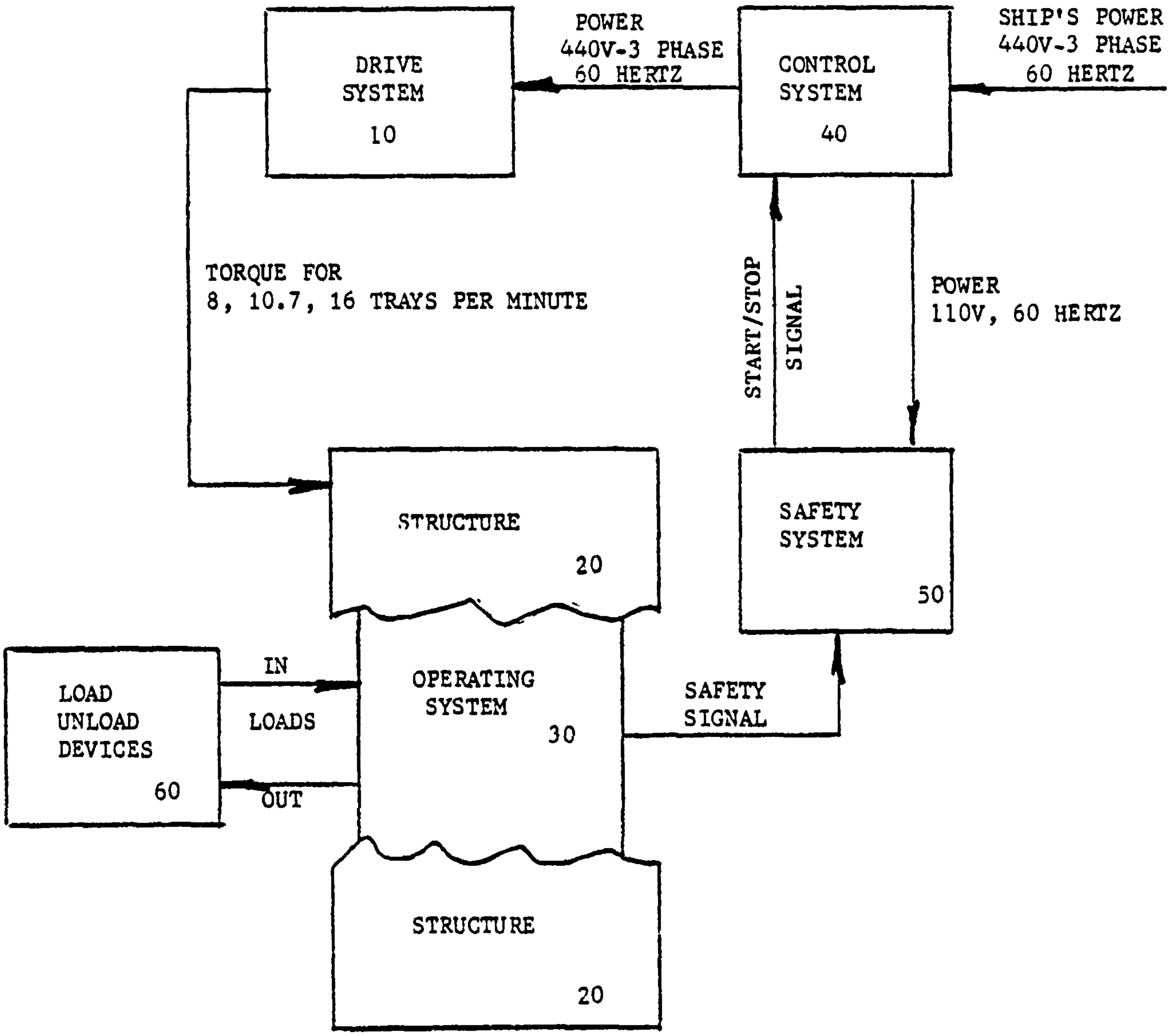
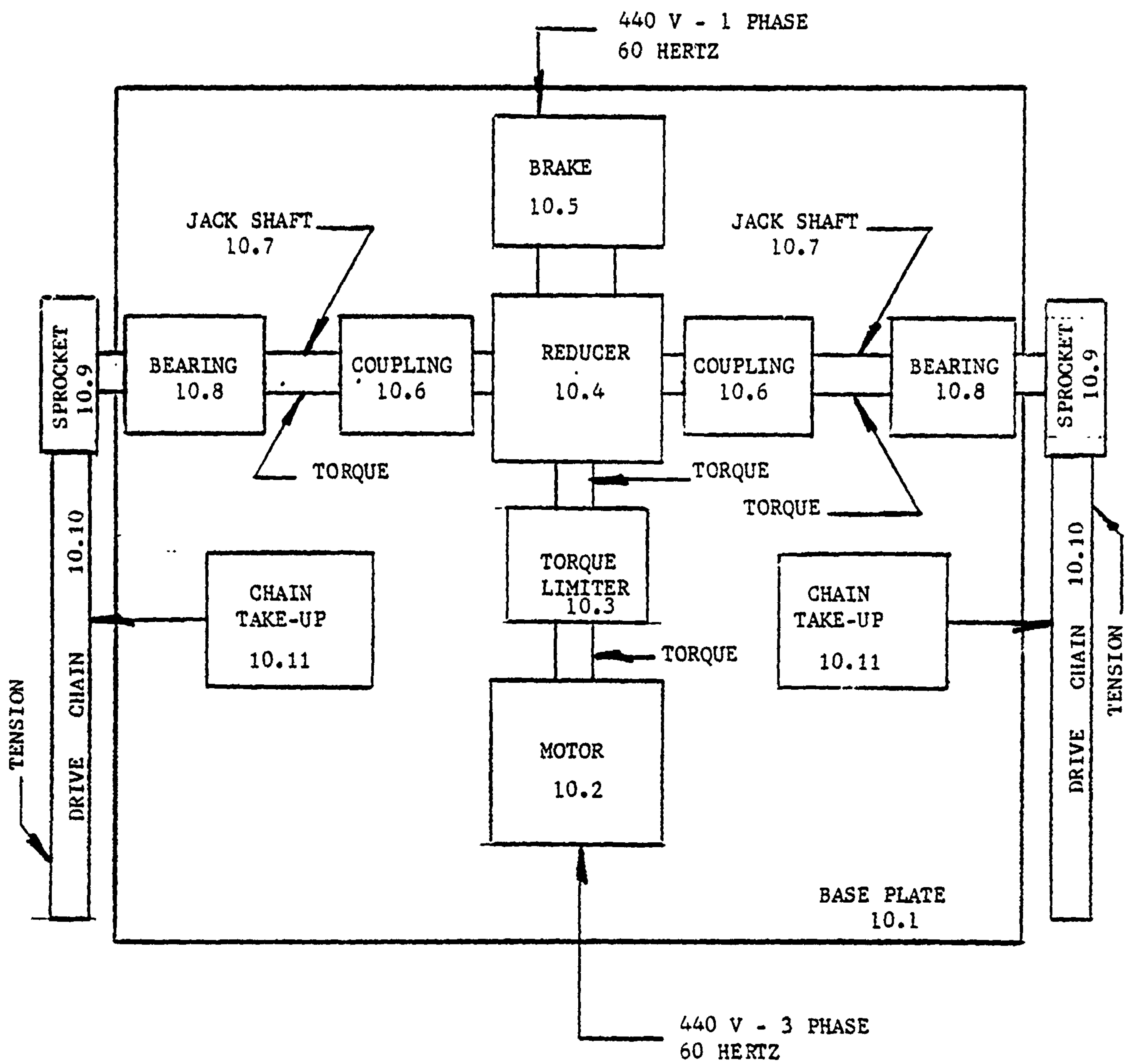


FIGURE NO. 1 Second indenture level functional block diagram.



NOTE: All components are sized and rated as a function of conveyor loading.

FIGURE NO. 2 Third indentured level functional block diagram for drive system (Number 10)

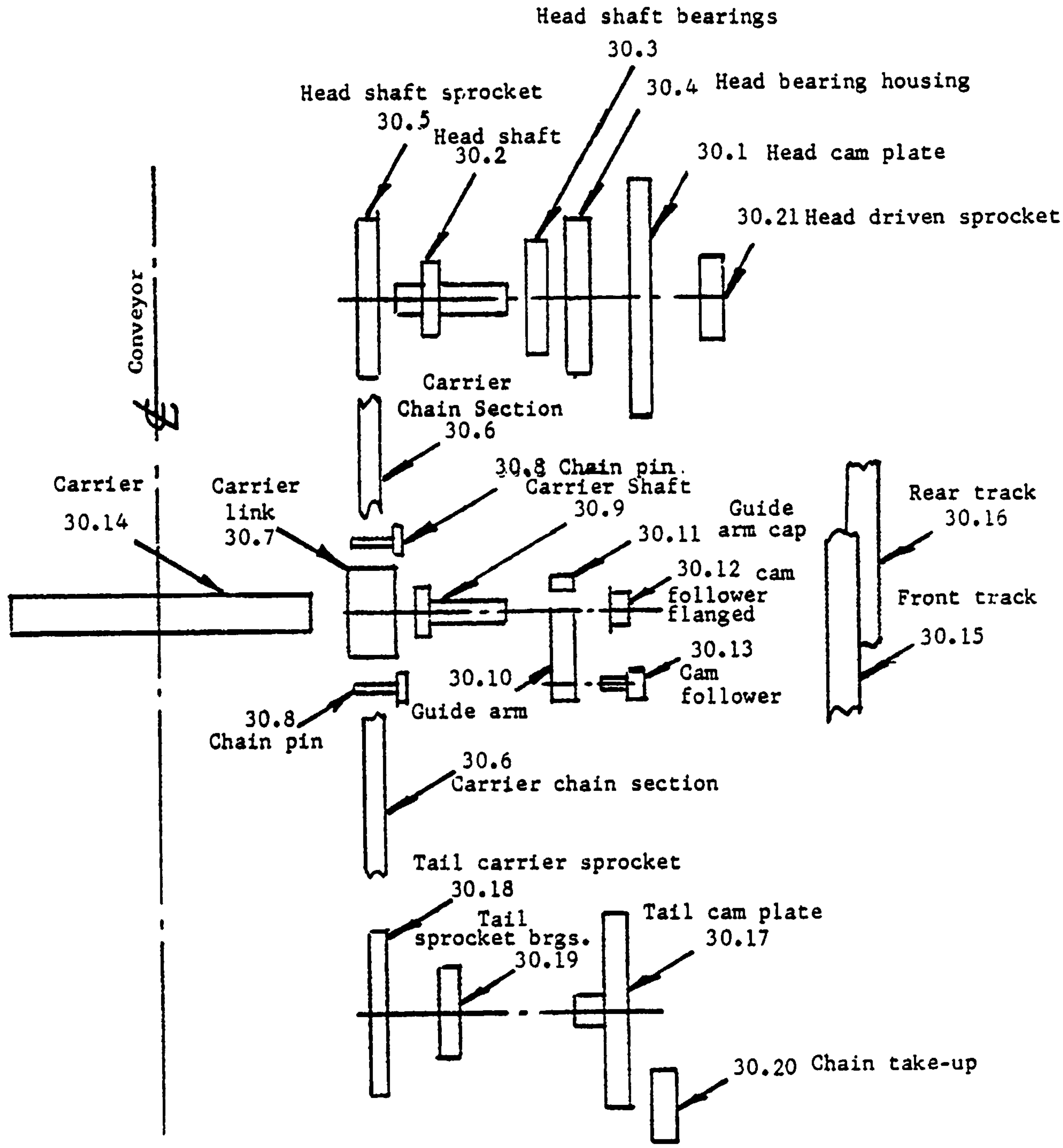


FIGURE NO. 3 Third indentured level functional block diagram for operating system (Number 30)

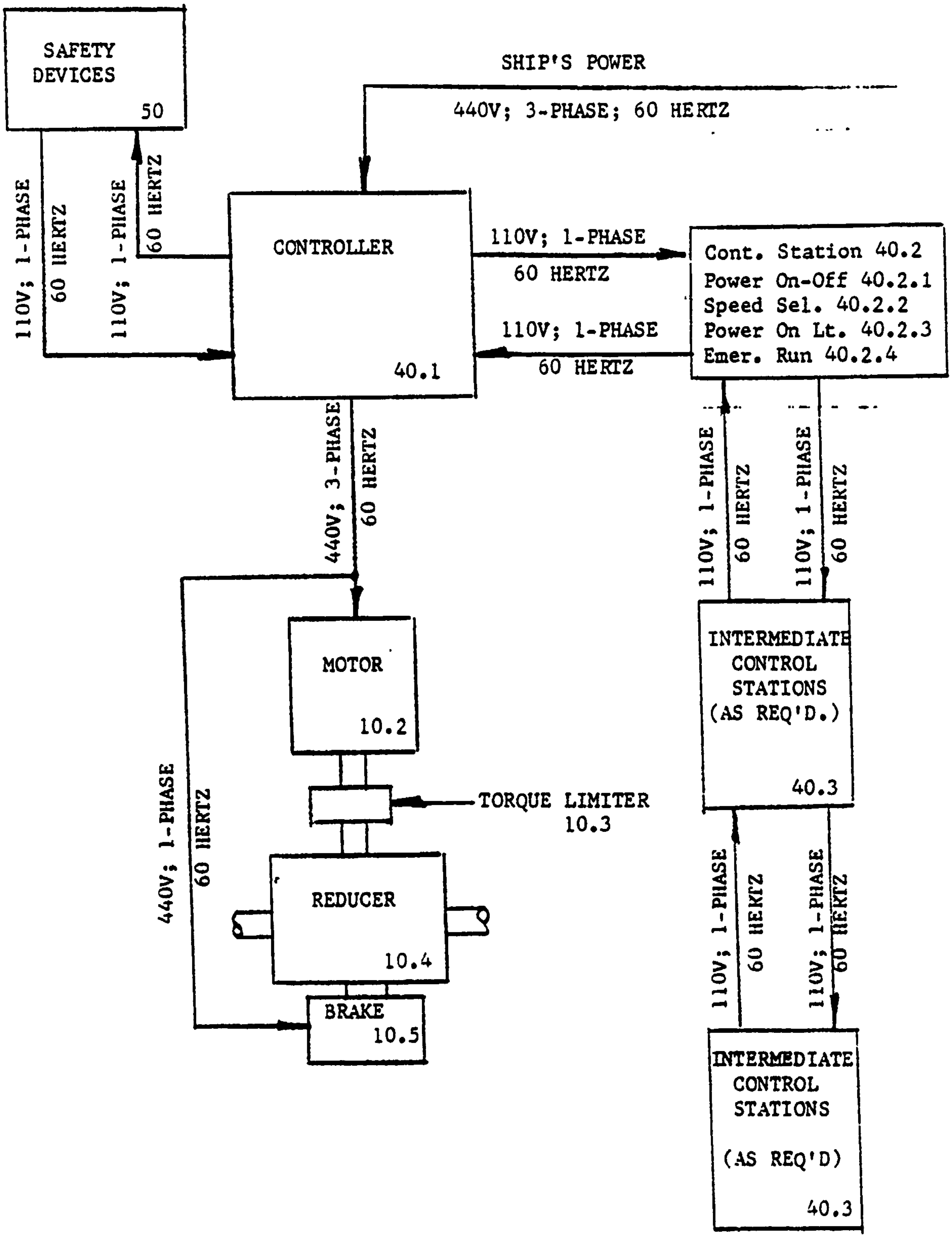


FIGURE NO. 4 Third indentured level functional block diagram for the control system (Number 40).

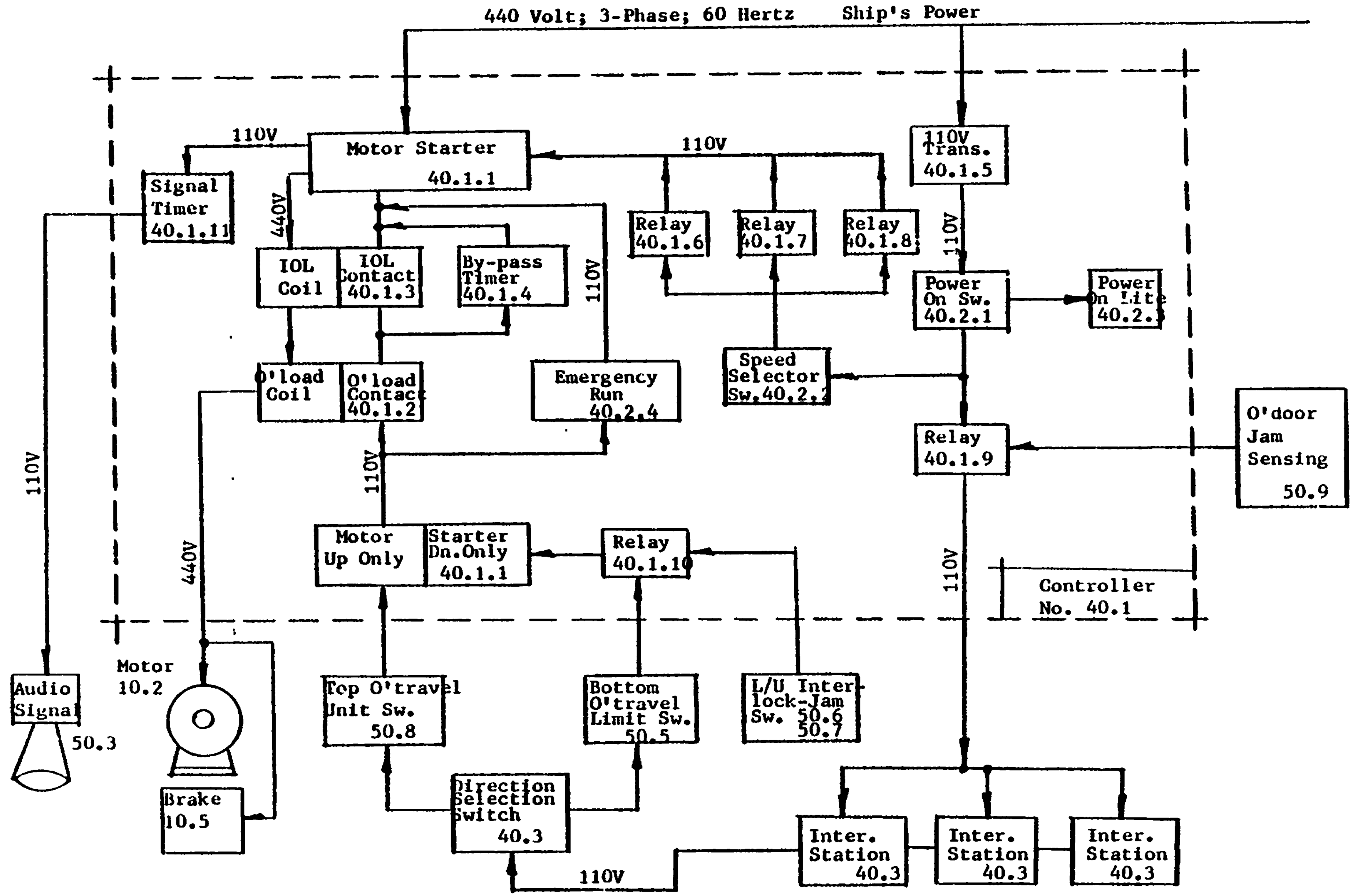


Figure No. 5
Fourth Indenture Level Functional Block
Diagram of the Elements of the Controller (40.1)

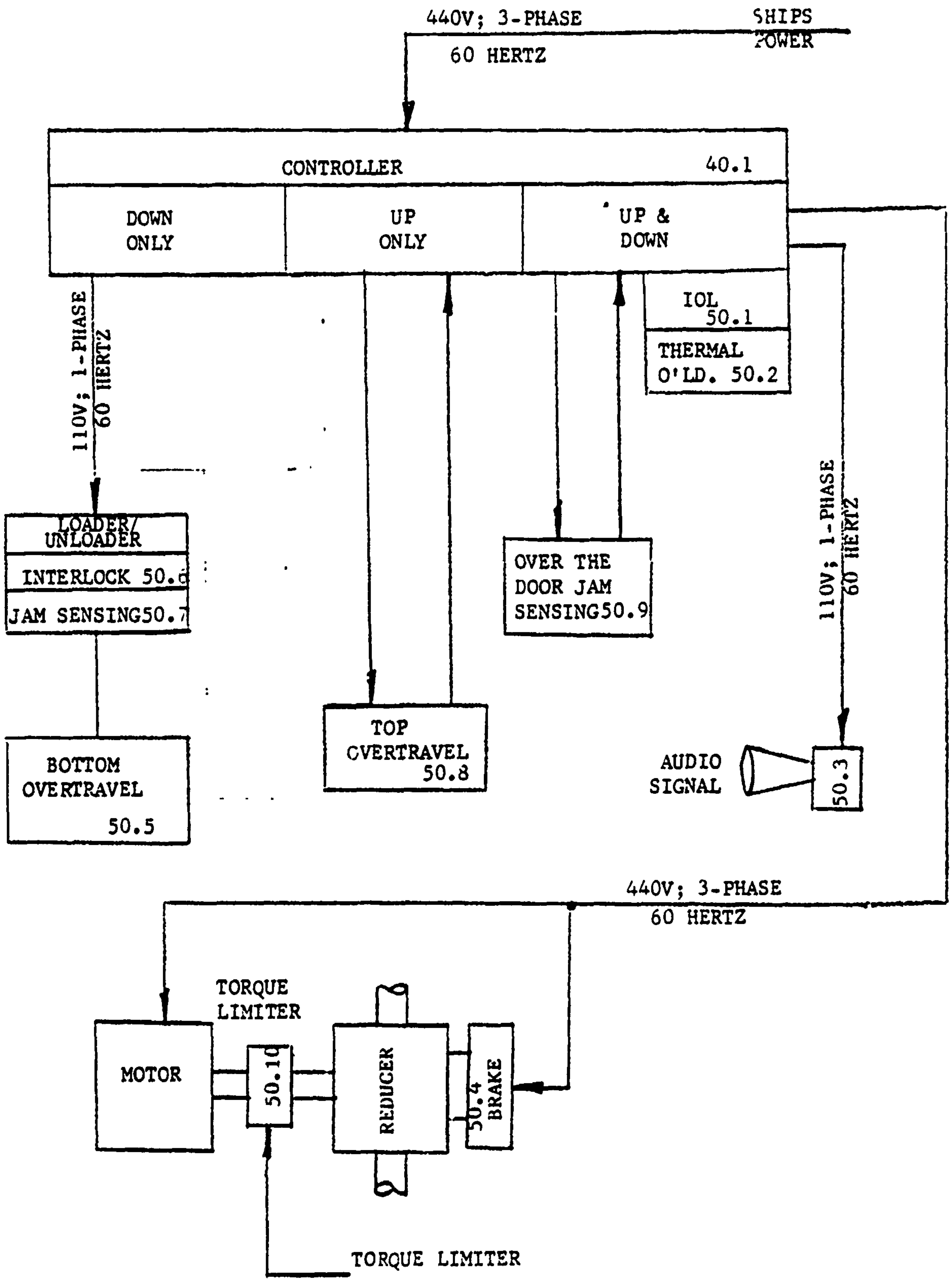


FIGURE NO. 6 - Third indentured level functional block diagram for safety devices (Number 50).

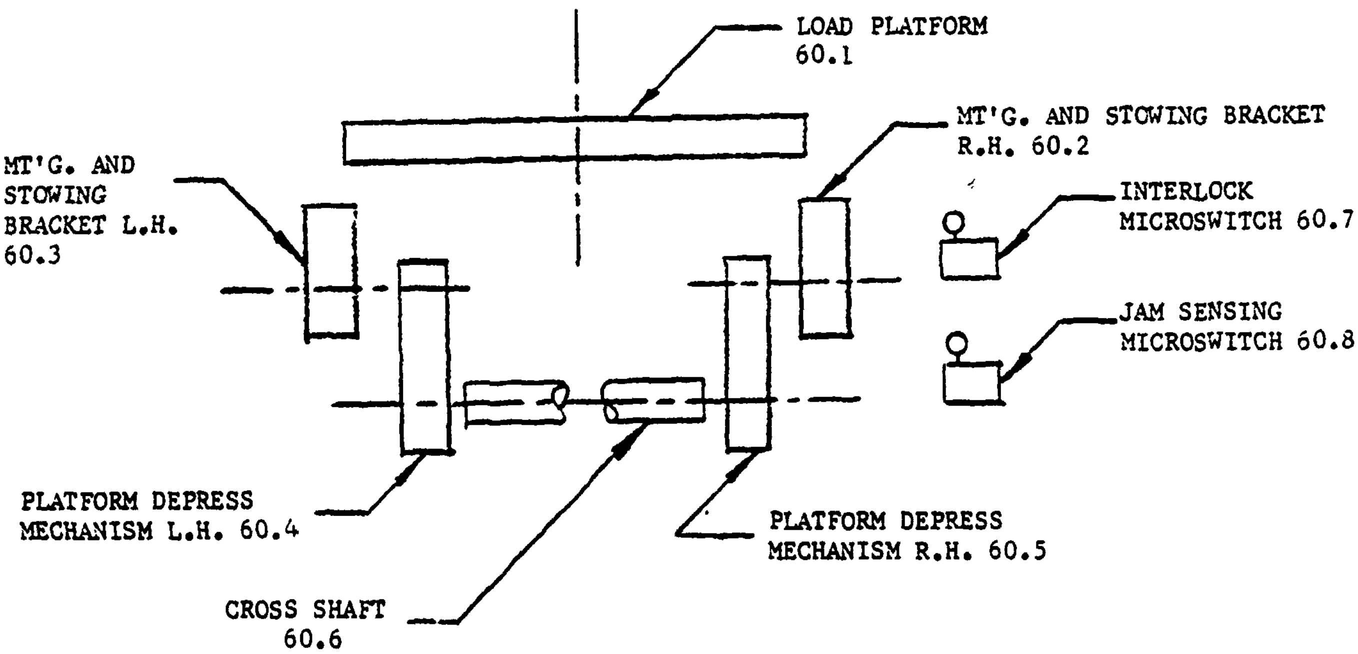


FIGURE NO. 7 - Third level indentured functional block diagram for the load/unload device (Number 60).

PROBABILITY \ SEVERITY	1	2	3	4
4				
3				
2	10.3.01 10.3.02			
1	10.2.02 10.3.04 10.5.02 10.5.03 10.5.04 10.5.05 10.5.06 10.11.02 10.11.03	10.2.03 10.3.03 10.3.05 10.5.01 10.8.02 10.11.01	10.2.04 10.2.05 10.4.02 10.4.03 10.6.01 10.7.01 10.9.01	10.2.01 10.4.01 10.4.04 10.6.02 10.6.03 10.7.02 10.7.03 10.8.01 10.9.02 10.10.01

SEVERITY

Figure No. 8

CRITICALITY MATRIX - DRIVE SYSTEM (No. 10)

Matrix Tabulation - Drive System

	Level 3	Level 4
10.2 Motor	2	1
10.3 Torque Limiter	0	0
10.4 Reducer	2	2
10.5 Brake	0	0
10.6 Coupling	1	2
10.7 Jack Shaft	1	2
10.8 Bearing	0	1
10.9 Drive Sprocket	1	1
10.10 Drive Chain	0	1
10.11 Chain Take-up	0	0

Figure No. 8 (a)

Tabulation for Drive System (No. 10)

PROBABILITY	1	2	3	4
4				
3				
2				
1	20.1.02	20.1.01		

SEVERITY

Figure No. 9

CRITICALITY MATRIX - CONVEYOR STRUCTURE (20)

Matrix Tabulation - Convevor Structure

	Level 3	Level 4
20.1 Trunk	----	----

Figure No. 9 (a)

Tabulation for Conveyor Structure (No. 20)

PROBABILITY	Severity 1	Severity 2	Severity 3	Severity 4
4				
3				
2		30.1.01 30.14.01 30.15.01 30.16.01	30.9.01	30.1.02 30.15.02 30.16.02 30.17.02
1		30.2.04 30.3.02 30.5.01 30.7.02 30.18.01 30.19.02 30.20.01	30.2.01 30.7.01 30.21.01	30.2.02 30.2.03 30.3.01 30.4.01 30.5.02 30.6.01 30.8.01 30.10.01 30.11.01 30.19.01 30.21.02

SEVERITY

Figure No. 10

CRITICALITY MATRIX - OPERATING SYSTEM (No. 30)

Matrix Tabulation - Operating System

	Level 3	Level 4
30.1 Head Cam Plate	0	1
30.2 Head Shaft	1	2
30.3 Head Shaft Bearing	0	1
30.4 Head Bearing Housing	0	1
30.5 Head Shaft Sprocket	0	1
30.6 Carrier Chain	0	1
30.7 Carrier Link	1	0
30.8 Chain Pin	0	1
30.9 Carrier Shaft	1	0
30.10 Guide Arm	0	1
30.11 Guide Arm Cap	0	1
30.12 Cam Follower Flanged	0	0
30.13 Cam Follower	0	0
30.14 Carrier	0	0
30.15 Front Track	0	1
30.16 Rear Track	0	1
30.17 Tail Cam Track	0	1
30.18 Tail Carrier Sprocket	0	0
30.19 Tail Sprocket Bearings	0	1
30.20 Chain Take-up	0	0
30.21 Head Driven Sprocket	1	1

Figure No. 10 (a)

Tabulation for Operating System (No. 30)

PROBABILITY \ SEVERITY	1	2	3	4
4				
3				
2				
1	40.1.1.1 40.1.1.2 40.1.1.3 40.1.6.1 40.1.6.2 40.1.7.1 40.1.7.2 40.1.8.1 40.1.8.2 40.2.3.1 40.2.4.2 40.3.1.1	40.1.2.2 40.1.5.1 40.1.9.2 40.1.10.2 40.1.11.1 40.2.4.1 40.2.2.1 40.2.2.2	40.1.3.1 40.1.4.1 40.1.4.2 40.1.4.3 40.1.9.1 40.1.10.1 40.2.1.1 40.3.3.1 40.3.3.2 40.3.4.1 40.3.4.2	40.1.2.1 40.2.2.3 40.3.2.1 40.3.2.2

SEVERITY

Figure No. 11

CRITICALITY MATRIX - CONTROL SYSTEM (No. 40)

Matrix Tabulation - Control System

		Level 3	Level 4
40.1.1	Reversing Starter	0	0
40.1.2	Thermal Overload	0	1
40.1.3	Instantaneous Overload Relay	1	0
40.1.4	IOL By-pass Timer	3	0
40.1.5	110V. Transformer	0	0
40.1.6	First Speed Relay	0	0
40.1.7	Second Speed Relay	0	0
40.1.8	Third Speed Relay	0	0
40.1.9	Overdoor Jam Relay	1	0
40.1.10	Load/Unload Relay	1	0
40.1.11	Signal Timer	0	0
40.2.1	Power On/Off Switch	1	0
40.2.2	Three-position Speed Switch	0	1
40.2.3	Power "On" Light (Red)	0	0
40.2.4	Emergency Run Switch	0	0
40.3.1	Power "On" Light (Green)	0	0
40.3.2	Stop Push-On Pull Switch	0	2
40.3.3	"Up" Push Button	2	0
40.3.4	"Down" Push Button	2	0

Figure No. 11 (a)

Tabulation for Control System (No. 40)

PROBABILITY				
4				
3				
2				
1	50.3.01 50.3.02 50.3.03	50.5.02 50.6.02 50.7.02 50.8.02 50.9.02		50.5.01 50.6.01 50.7.01 50.8.01 50.9.01
	1	2	3	4

SEVERITY

Figure No. 12

CRITICALITY MATRIX - SAFETY DEVICES (50)

Matrix Tabulation - Safety Devices

		Level 3	Level 4
50.1	Instantaneous Overload	(see 40.1.3)	
50.2	Thermal Overload	(see 40.1.2)	
50.3	Audio Signal	0	0
50.4	Brake	(see 10.5)	
50.5	Bottom O'Travel Limit	0	1
50.6	Load/Unload Interlock Switch	0	1
50.7	Load/Unload Jam Switch	0	1
50.8	Top O'Travel Limit	0	1
50.9	Over Door Jam Switch	2	1
50.10	Torque Limiter	(see 10.3)	

Figure No. 12 (a)

Tabulation for Safety Devices

PROBABILITY \ SEVERITY	1	2	3	4
4				
3				
2				
1	60.4.04 60.4.05 60.5.04 60.5.05	60.1.01		60.2.01 60.3.01 60.4.01 60.4.02 60.4.03 60.4.06 60.5.01 60.5.02 60.5.03 60.5.06 60.6.01

SEVERITY

Figure No. 13

CRITICALITY MATRIX - LOAD/UNLOAD DEVICE

Matrix Tabulation - Load/Unload Device

		Level 3	Level 4
60.1	Platforms	0	0
60.2	Mounting and Stowing Bracket R. H.	0	1
60.3	Mounting and Stowing Bracket L. H.	0	1
60.4	Platform Depress Mechanism L. H.	0	4
60.5	Platform Depress Mechanism R. H.	0	4
60.6	Cross Shaft	0	1
60.7	Interlock Micro-switch	(see 50.6)	
60.8	Jam Sensing Micro-switch	(see 50.7)	

Figure No. 13 (a)

Tabulation for Load/Unload Device

PROBABILITY				
4				
3				
2	2* 1.5%**	4* 3.0%**	1* 0.8%**	4* 3.0%**
1	29* 22%**	28* 22%**	21* 16%**	41* 31.5%**
	1	2	3	4

*Number of Potential Failures SEVERITY
** Percent of Total

Figure No. 14

CRITICALITY MATRIX - OVERVIEW OF ALL SECTIONS

Section VI

Calculations

The following pages contain detailed revised stress calculations for the de-rated jam conditon. A supplement to these calculations is also provided. Prior to submitting the revised calcu.ations to Naval Ship Engineering Center on November 10, 1976 and the supplement on April 5, 1977, the Contractor provided a complete set of calculations for Phase I which were subsequentally revised and re-submitted as part of Phase II on November 18, 1975. The earlier, November 18, 1975, Calculation submittal is not being included in this final report in order to conserve space and minimize reproduction cost.

SUPPLEMENT

DE-RATED JAM CONDITION

PER S. OTTO'S TELEPHONE CONVERSATION OF 3-29-77

CDRL ITEM B001AL

USN CONTRACT N00024-72-C-5500

OF NOVEMBER 3, 1976

Submitted: 13 April 1977

By: Kornylak Corporation

Hamilton, Ohio

Summary of telephone conversation of 3-29-77 between S. Otto and R. arson - with replies.

Attn: V. Doty
R. Martin

1. Liked R. Martin's stress calculation work!

   - Thanks, Bob Martin

2. Questions size of finger-to-backbone welds on load trays. Where stated?

   - Will appear on fabrication drawings as ¼" fillet welds - as noted on page (8) of report.

3. Suggested Bob check stress concentrations at keyway of carrier shaft.

   - See page B and C attached.

4. Requested Bob re-do stress calculations of carrier shaft where it ties to guide arm and add approximately 1300# shear load to torsion load (referring to Fig. 11-A).

   - See page C attached.

5. Requested that Kornylak send letter to delete 150# - four foot drop spec. requirement since this load impossible for design to survive.

   - See page D attached.

Item 3 of 3-29-77 telephone conversation .... stress concentrations at keyway of carrier shaft:

Reference: Report page 13; Roark's "Formulas for Stress & Strain" 4th edition, page 334

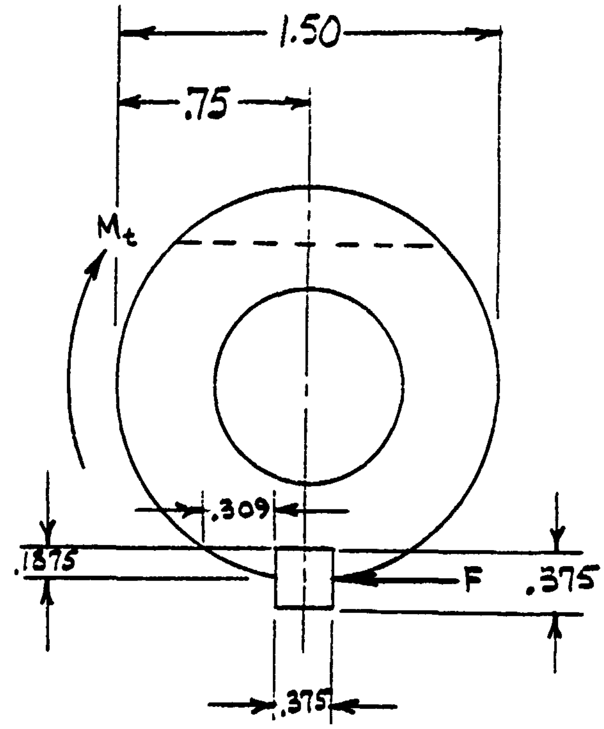
Assuming that the key takes the entire load (no cap) and that the torsional moment produces a true horizontal force that tries to compress and shear through the shaft:

Torsional Moment M_t: 3069 in. lbs.
Shaft Radius: .75 inches
Key: 3/8 sq. x 1¼" lg.

$$\text{Force} = \frac{M_t}{\text{shaft rad.}} = \frac{3069}{.75} = 4092 \text{ lbs.}$$

$$\text{Compressive Stress} = \frac{F}{\text{Comp. Area}} = \frac{4092}{1.25 \times .1875} = 37{,}248 \text{ psi}$$

$$\text{Shear Stress} = \frac{F}{\text{Shear Area}} = \frac{4092}{1.25 \times .309} = 22{,}601 \text{ psi}$$



Supplement to Fig. 11_C

While the compressive stress of 37,248 psi is less than the allowable 48,000 psi for stainless steel, the shear stress of 22,601 psi will exceed the allowable 18,000 psi.

However, since according to Roark, "Photoelastic Analysis of the stress in square keys shows that the shear stress is not uniform across the breath" ...... but is greater in the corners tending to rock the key, especially since the carrier shaft is subject to pulsations. (Reference Fig. 11_D)

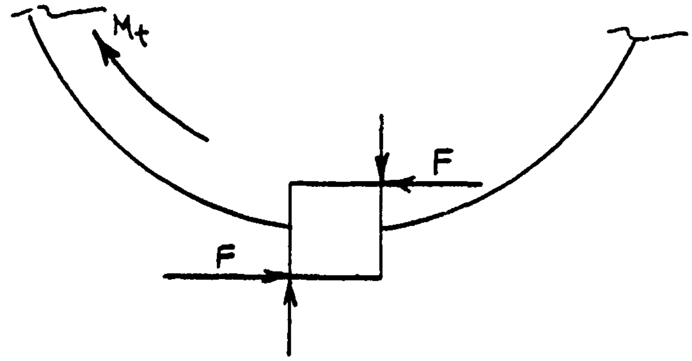


Fig 11_D

Therefore, since the key is rocking, direct shearing through the shaft is not the true case; moreover, the cap would surely limit the shear stress to less than the allowable 18,000 psi if it were.

Roark concluded the key stress segment: "When conservative working stresses are used, however, and the proportions of the key are such as have been found satisfactory in practice, the approximate methods of stress calculation that have been indicated result in satisfactory design". Which is the case as used in the report.

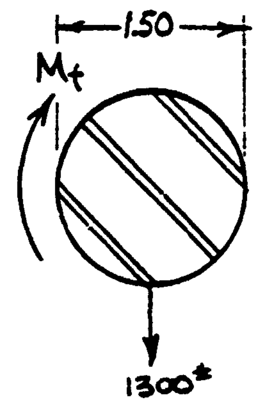
Item (4) of 3-29-77 telephone conversation ...... add 1300# shear load to carrier shaft where it ties to guide arm.

Reference: Drawing 2-1026-SC3

The 1300# shear load (chain pull) was neglected with respect to Fig. 11_A because where the carrier shaft ties to the guide arm there is no fixed restraint (direct shear). The guide arm is trying to pivot about the cam roll which is pure torsional shear.

I can, however, place the neglected 1300# shear load on the opposite side of the carrier link where the cross section is full.

Area of 1½" ø shaft = 1.76 sq. inch



$$\text{Torsional Shear} = \frac{M_t}{\text{rad. x area}}$$

$$= \frac{3069}{.75 \times 1.76} = 2325 \text{ psi}$$

$$\text{Direct Shear} = \frac{1300}{1.76} = 739 \text{ psi}$$

Total Shear = 2325 + 739 = 3064 psi

Since the allowable shear for Type 304 Stainless Steel is 18,000 psi, the carrier shaft is adequate for the application.

OPERATING SHOCK LOAD

Reference: (a) Para. 3.5.23.4 of Spec. SHIPS-C-5552

(b) Operating Shock Load Calculations Sht. 1 through 5

(c) Impact test results Sht. 1 through 4

(d) Shock Load Test per Para. 4.3.5 of SHIPS-C-5552

1. The impact loading as specified in reference (a) and (d) is too excessive and destructive, as pointed out in reference (b) and (c), and would require an increase in size of components which would not be practical or in keeping with the conveyor design.

In view of this, we recommend that para. 3.5.23.4 and 4.3.5 be deleted from the spec. and that the dynamic and static overload tests per para. 4.3.2 and 4.3.3 are sufficient for testing the conveyor.

REVISED STRESS CALCULATIONS

FOR

DE-RATED JAM CONDITION

CDRL ITEM B001AL

USN CONTRACT N00024-72-C-5500

NOVEMBER 3, 1976

Submitted: November 3, 1976

By: Kornylak Corporation

Hamilton, Ohio

The following drawings and reports are referred to in the text of this report:

2-1026-P20F-Rev. A	(Carrier Assembly)
2-1026-P26-Rev. B	(Carrier)
2-1026-P27-Rev. A	(Guide Arm)
2-1026-P28-Rev. B	(Carrier Shaft)
2-1026-47F-Rev. A	(Cap)
*2-1026-SCI/J	(Shaft & Bearing Calculations - Jam)
*2-1026-SC2	(Carrier Calculations)
*2-1026-SC3	(Carrier Shaft & Guide Arm Calculations)
**2-1026-SC3/J	(Carrier Shaft & Guide Arm Calculations - Jam)

Track System calculations for jam condition in letter of transmittal dated October 14, 1976

*These drawings were superseded, and prints of them are included with this report.

**This drawing was voided, and prints of it are included with this report.

REVISED STRESS CALCULATIONS FOR DE-RATED JAM CONDITION

DE-RATED JAM CONDITION

The jam condition was de-rated from motor stall torque to 115% live load setting on the torque limiter by N.E.V.E.C.'S amendment letter of May 20, 1976, modification No. P00014 revising Par. 3.5.23.1, Line 5, as clarified in Design Review Meeting held June 21 through June 23, 1976.

Live Load = 20 trays x 100# each

= 2000# x 1.15 = 2300# (torque limiter slip setting)

"The load is to be spread equally over four fingers of the tray".

Case I: One side finger and three intermediate fingers.

Case II: Four intermediate fingers (worst condition)

$\frac{2300\#}{4 \text{ fingers}} = 575\#$

Side View   End View

Fig. 1
Case II

Case II-A   Carrier Finger (Ref. Dwg. 2-1026-P26-Rev. B)
- Mat'l.: ASTM A513

Jam Stress Calculations (Ref. Dwg. 2-1026-SC2)
Per Fig. 2

Assuming no gusset as shown on drawing

Load WL = 575# uniform cantilever

Effective Length L = 21.125 inches

Finger Section Modulus Z = 0.334

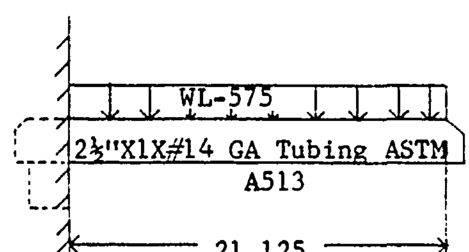


Fig. 2

Finger Loading
(without gusset)

Bending Moment

$$M_b = \frac{WL \times L}{2} = \frac{575 \times 21.125}{2} = 6073 \text{ in. lbs}$$

Bending Stress

$S_b = \frac{M}{Z} = \frac{6073}{0.334} = 18{,}160$ psi

Therefore, since the 18,160 psi is less than 26,600 psi, or the allowable combined stress per Spec. 3.5.23.1 (0.7 yield stress), the finger tubing is adequate for bending in this application.

Case II-B Finger Welds (neglecting bar gusset) - (Ref. dwg. 2-1026-P26 Rev. B)

Max. Allowable Shear Stress = 22,800 psi (ASTM A513)

Bending Moment M_b = 6073 in. lbs.

Req'd. Min. Section Modulus Z

$Z = \frac{M_b}{S_s} = \frac{6073}{22{,}800} = 0.266$

NOTE: $Z = \frac{I}{C}$

where I = Moment of Inertia,

and C = Distance from neutral axis to outermost fiber (inches)

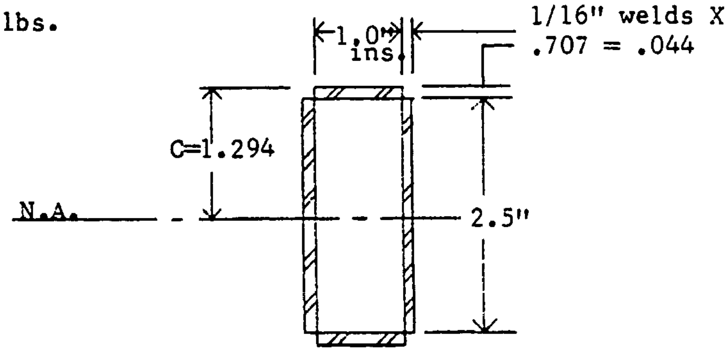


fig. 3_A
Finger weld (To Crossmember)
Using throat area

Neglecting bar gusset between finger and crossmember per Fig. 3_A

Recommended fillet weld thickness for #14 ga. tubing is 1/16" (.0625)

From the parallel axis theorem, using throat area of welds (.707 x leg):

Moment of Inertia of the welds $I_w = 0.258$

C Welds = 1.294

Section Modulus $Z_w = \frac{I_w}{C_w} = \frac{0.258}{1.294} = 0.199$

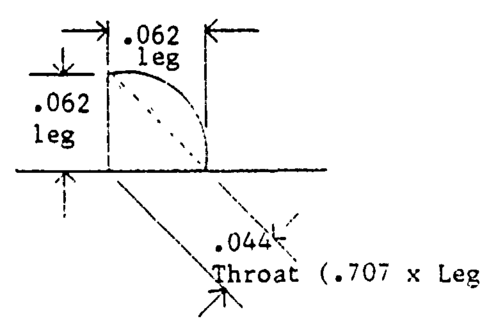


Fig. 3_B
Weld Enlargement

Bending Shear Stress $S_s = \frac{M}{Z_w} = \frac{6073}{.199} = 30{,}517$ psi

Therefore, since the section modulus of the welds, 0.199 (neglecting the bar gusset) is less than the minimum required section modulus of 0.266, (30,517 psi exceeds the allowable shear stress of 22,800 psi) the finger welds <u>are</u> <u>not</u> adequate for this application.

To reduce the bending shear stress of the finger welds, add a gusset between the finger and crossmember so as to reduce the bending moment.

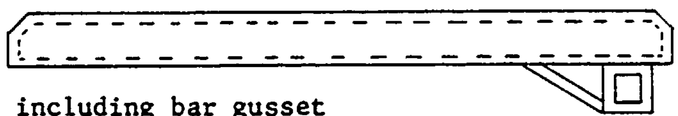


Fig 4_A

Finger with Gusset

Case II B Finger Welds including bar gusset per Fig. 4 - (Ref. Item 3 on Dwg. 2-1026-P26 Rev. B)

Gusset: 3/8" x 1" AISI 1020 HRS Bar x 5" Lg.

Assuming the gusset is strong enough to resist bending:

Revised Effective Length L = 16.625"

Revised Bending Moment M_b (using entire uniform load @ L = 16.625" for worst condition)

$$M_b = \frac{575 \times 16.625}{2} = 4780 \text{ in. lbs.}$$

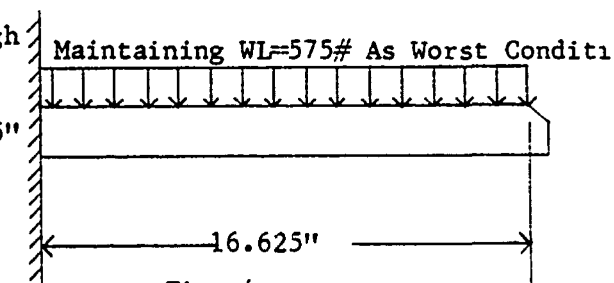


Fig. 4_B

Finger Loading With Gusset

Revised Req'd Section Modulus of the welds Z_w

$$Z_w = \frac{M_b}{S_s\ (\text{max.})} = \frac{4780}{22{,}800} = 0.210$$

From the parallel axis theorem, using throat area of welds (.707 x leg)

Moment of Inertia $I_w = 1.684$

$C_{welds} = 5.34$

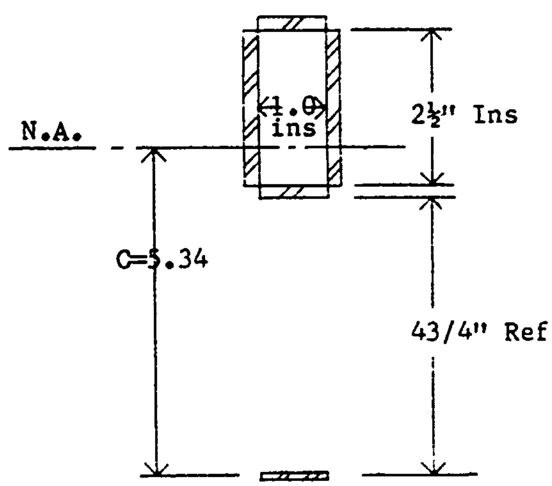


Fig. 4_C

Finger Welds Incl. Gusset

Using throat area

Section Modulus Z_w

$$Z_w = \frac{I_w}{C_w} = \frac{1.684}{5.34} = 0.315$$

Bending Shear Stress on the welds $S_s = \frac{M_b}{Z_w} = \frac{4780}{.315} = 15{,}175$ psi

Considering the additional strength that the bar gusset weld adds to the finger welds, the section modulus of 0.315 exceeds the min. required section modulus of .210 (15,175 psi is less than the allowable shear stress of 22,800 psi). Therefore, the finger welds are adequate for the application.

To confirm the additional strength that the bar gusset adds to the finger welds, the following physical tests were made on two different carrier fingers.

Finger I: 2½" x 1" x #14 Ga. Finger Plain, i.e., no gusset

Finger II: 2½" x 1" x #14 Ga. Finger with 3/8" x 1" x 5" lg. bar Gusset per dwg. 2-1026-P26-Rev. B

Both fingers were subjected to the rated load, and then additional weight was added until the first sign of failure was observed, documenting weights, deflections and mode of failure(s).

Note: A third finger with a 2½" x 1" x 14 ga. mitered tube gusset was also tested at the same time as the other two (ref. Fig. 5_C); however, tests results showed that it was no stronger than the bar gusseted finger (Fig. 5_B).

TESTS AND RESULTS PER PAGES 5,6,7, & 8

BENDING SHEAR TESTS ON CARRIER FINGER WELDS

These three carrier fingers were loaded as shown to test the strength of the welds joining them to the crossmember, and also to test what effect the gussets had on them.

Finger I
no gusset

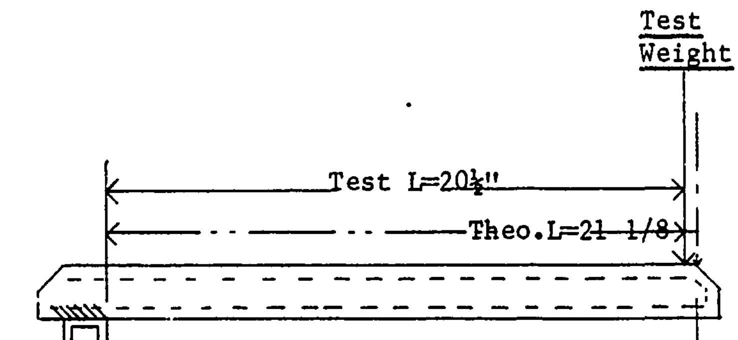


Fig. 5_A

Finger II
with bar gusset

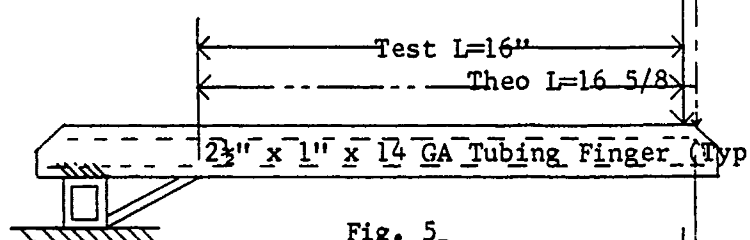


Fig. 5_B

Finger III
with tube gusset

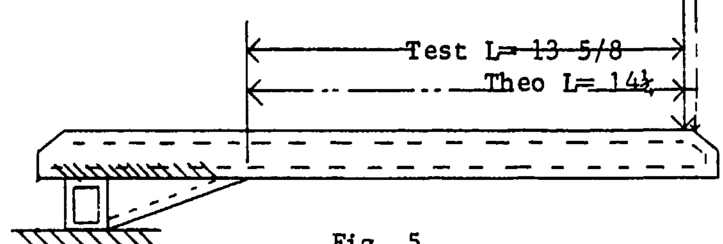
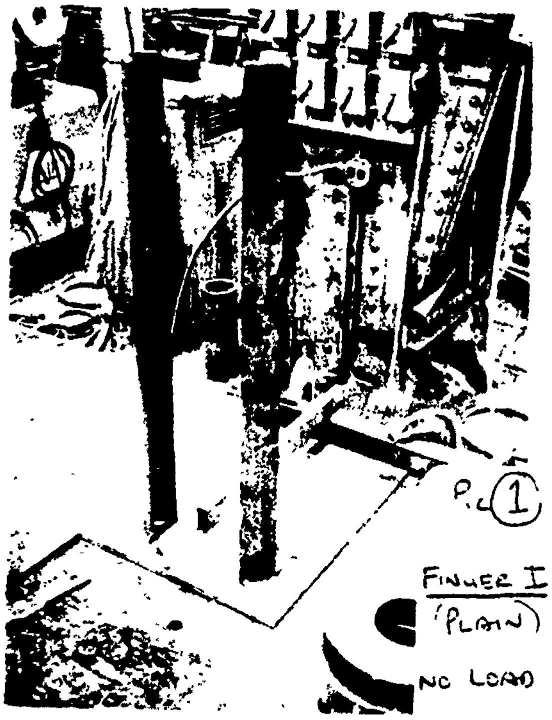


Fig. 5_C

TEST	WEIGHT LBS.	DEFLECT. INCHES	DEFORM. SET INCHES	DESCRIPTION FAILURE MODE	COMMENTS
Finger I	303 877 1059	0.125 0.375 0.406	0 0 0.125	Finger Bent	Welds O.K. See Pics. 1,2,3,4, &5
Finger II	303 877 1059	0.062 0.250 0.281	0 0 0	None	Welds O.K. See Pic. 6
Finger III	303 877 1059	0.062 0.218 0.281	0 0 0	None	Welds O.K. See Pic.7

PICTURES TAKEN DURING FINGER WELD TESTS



Pic 1

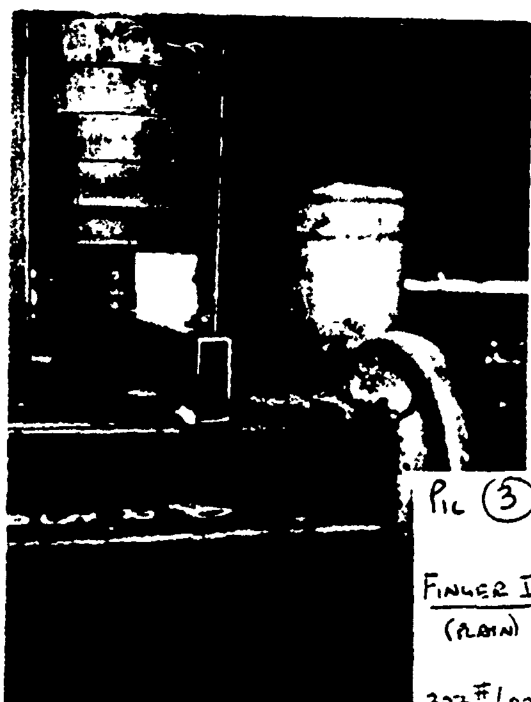
Finger I (Plain)

No Load

Pic 2

Finger I (Plain)

303# Load



Pic 3

Finger I (Plain)

303# Load

Pic 4

Finger I (Plain)

877# Load

PICTURES TAKEN DURING FINGER WELD TESTS

Pic (5)
FINGER I
(PLAIN)
1059# LOAD

Pic (6)
FINGER II
w/BAR GUSSET
303# LOAD

Pic (7)
FINGER III
w/ TUBE GUSSET
303# LOAD

The results of the tests indicate more than the strength value of the gusset, however, as the welds themselves withstood over 3½ times the weight of the rated load at jam condition.

NOTE: While the recommended fillet weld thickness for #14 ga. tubing is 1/16", the mig-welded ¼" fillet welds, applied to the fingers at the crossmember, supported 1059# without failure in bending shear which is equivalent to a section modulus of .952 for the welds; hence, considering throat area of the welds (.707 x leg), they are equivalent to a fillet leg thickness of over 5/16" (.3125), which is stronger than the parent metal thickness of .075" (#14 ga.)

Calculations:

Max. Allowable Shear Stress (ASTM A513) S_s = 22,800 psi

Max. Weight Used Without Failure W = 1059# (plain finger, i.e., no gusset)

Bending Moment M_b = W x L (Point Load, Cantilever)

= 1059 x 20.5"

= 21,710 in. lbs.

Bending Moment $M_b = \frac{WL \times L}{2}$ (Uniform Load, Cantilever)

Since jam condition was specified as a uniform load, the equivalent uniform load for a bending moment of 21,710 in. lbs. would be 2118# (3.68 x rated jam condition)

Section Modulus of the Welds $Z_w = \frac{M_b}{S_{s(max)}} = \frac{21,710}{22,800} = .952$

From Fig. 5_A, using an equivalent section modulus of .952 and a throat area (.707 x leg), from the parallel axis theorem, the fillet leg of the welds joining the finger to the crossmember calculates to a thickness in excess of 5/16".

Case II - C Crossmember (Ref. Dwg. 2-1026-P26-Rev. B)
- Mat'l.: ASTM A500

Load (W) = 575#, r places, simply supported

Section Modulus (Z) = 1.24

$M_{R_2}: R_1 = \frac{575(12 + 18 + 24 + 30)}{36}$

$R_1 = 1342\#$

$F_{vert}: R_2 = 958\#$

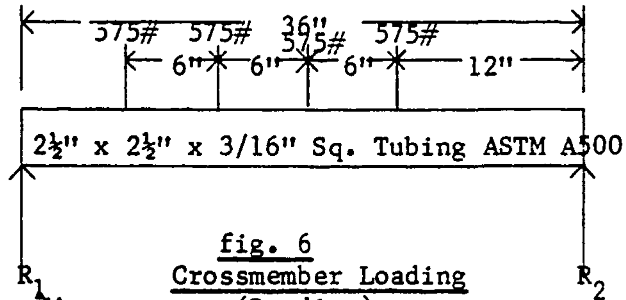


fig. 6
Crossmember Loading
(Bending)

Max. Bending Moment M_b = 13,806 in. lbs. from shear - mom. diag.

Max. Bending Stress = $S_b = \frac{M_b}{Z} = \frac{13,806}{1.24} = 11,134$ psi

Therefore, since 11,134 psi is less than 32,200 psi, the allowable combined stress per Spec. 3.5.23.1 (0.7 yield stress), the tubing is adequate for bending in this application.

Crossmember Stresses at Side Bar

Area (A) of crossmember = 1.74 sq. inc.

Max. Direct Shear Stress (Crossmember at side bar) $S_s = \frac{R_1}{A} = \frac{1342}{1.74}$

$= 771$ psi

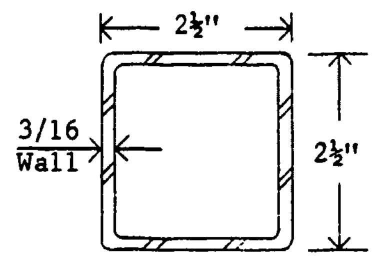


fig. 7_A
Crossmember Area

Torsional Moment M_t using uniform load acting through the center of the crossmember for worst condition

$M_t = \frac{575 \times 22.375}{2}$ (per finger) x 4 fingers x ½ (assuming symm. loading each end)

= 12,866 in. lbs. @ side bars

Torsional Section Modulus (Q) ref. Roark's "Formulas for Stress & Strain" pg. 196

$Q_{square} = 2t\ (\text{lgth. side} - t)^2$

$= 2\ (3/16)\ (2.5 - .1875)^2$

$= 2.01$

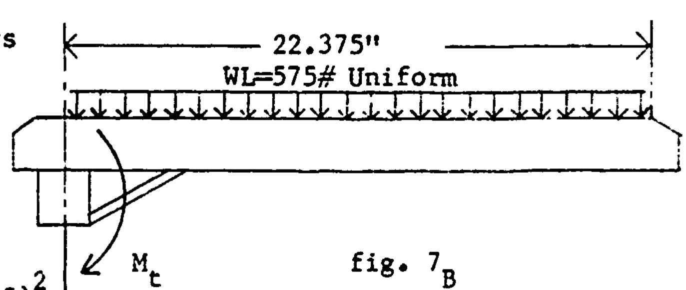


fig. 7_B
Crossmember Loading
(Torsion)

Torsional Shear Stress $S_t = \frac{M_t}{Q}$

$$= \frac{12{,}866}{2.01}$$

$$= 6{,}401 \text{ psi}$$

Therefore, since the direct shear of 771 psi and the torsional shear of 6,401 psi are respectfully less than the allowable direct shear of 27,600 psi and the torsional shear of 29,900 psi, the tubing is adequate for shear and torsion in this application.

Weld Stress (Crossmember to Side Bar)

Recommended fillet weld thickness for 3/16" tubing = 1/8" (0.125)

Total area of welds (A) = 0.88 sq. in. using throat area (.707 x leg)

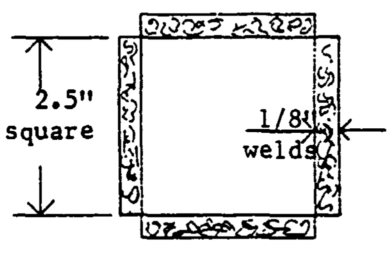


fig. 8_A
Crossmember Welds
(To side bar)

Max. Direct Shear Stress $S_s = \frac{R_1}{A} = \frac{1342}{0.88} = 1525$ psi

Torsional Section Modulus of the welds $Q_w = 2(.088)\ (2.676-.088)^2$

$$= 1.18$$

Ref. Roark's "Formulas for Stress & Strain" pg. 196 using throat area (.707 x leg)

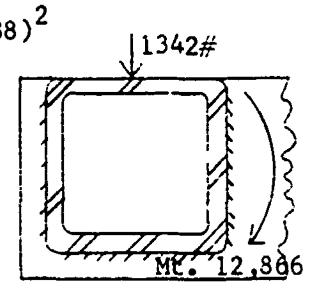


fig 8_B
Loads on Welds
Crossmember to Side Bar

Torsional Shear Stress welds $S_t = \frac{M_t}{Q_w} = \frac{12{,}866}{1.18} = 10{,}903$ psi

Therefore, as in the case of the crossmember proper, the welds joining the crossmember to the side bar are likewise adequate for this application.

Case II - D Carrier Shaft Mounting Bolts (Ref. Dwg. 2-1026-P20F Rev. A)
- Mat'l: MIL-B-857 Grade 2, 5/8-11 UNC

Area of Bolts (A) - 0.202 sq. in.
(Root Area)

F_{vert}: $R_1 = R_2 + 1342\#$

M_b : $R_2 = 51\#$

Therefore, $R_1 = 1393\#$

Combined Shear Stress
(direct & torsion)
from freebody diagram
using worst cond. (R_1)

$$S = \frac{P}{A} = \frac{1393}{.202} = 6,896 \text{ psi}$$

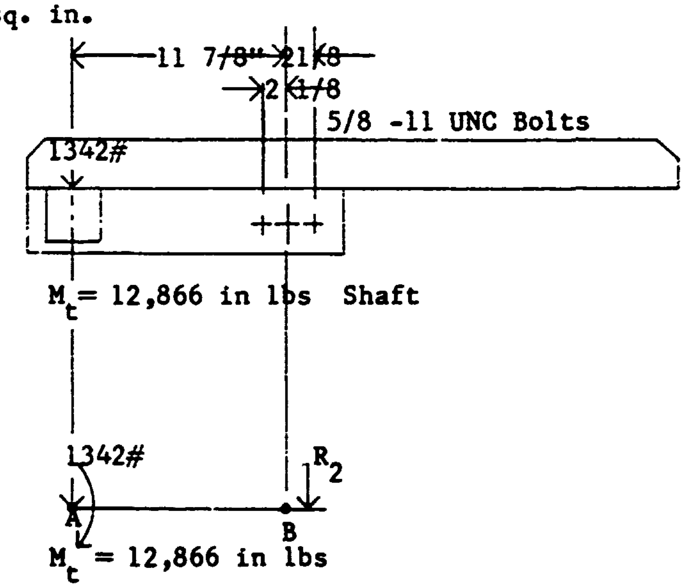


fig. 9
Physical & Freebody Diagram of Bolt Loading

Req'd Tensile Yield Stress

$$\text{Min. Tensile Y.S. (shear)} = \frac{\text{Actual Shear Stress}}{0.6}$$

$$= \frac{6,896}{0.6} = 11,493 \text{ psi}$$

Therefore, since the tensile yield stress of a 5/8-11 Grade 2 bolt is 64,000 psi per MIL-B-857, which exceeds the req'd 11,493 psi, they are adequate for this application.

Case II-E Carrier Shaft Welds (Ref. Dwg. 2-1026-P28-Rev. B)
- ¼" Fillet Welds

Jam Stress Calculations
per Fig. 10

Net Vert. Force = 1393 - 51 = 1342#

Area of ¼" fillet weld using throat area (.707 x leg) = 1.11 sq. in.

Direct Shear Stress on Welds

$$S_{sd} = \frac{F_y}{A} = \frac{1342}{1.11} = 1209 \text{ psi}$$

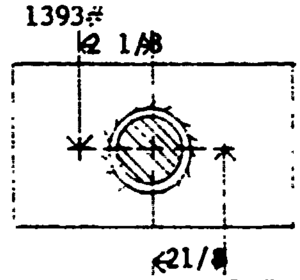


fig 10_A
Loading on Carrier Shaft Mounting Plate (from Bolts)

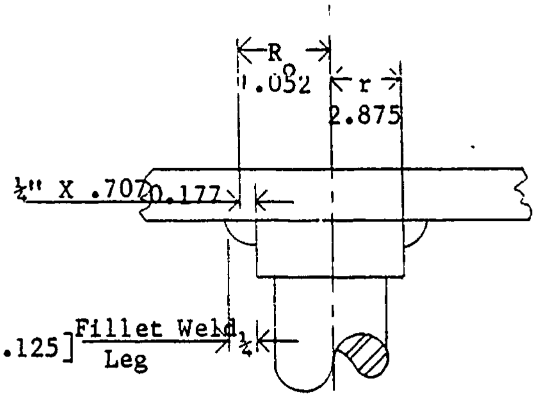


fig 10_B
Carrier Shaft Welds
(to mounting plate)

Torsional Moment M_t

$M_t = [1393 \times 2.125] + [51 \times 2.125]$

$= 3069$ in. lbs.

Torsional Section Modulus of the welds $Q_w = \dfrac{\pi\left[R_o^4 - r_i^4\right]}{2\,R_o}$

Ref. Roark's "Formulas for Stress & Strain" pg. 195 using throat area (.707 x leg)

$= \pi\left[(1.052)^4 - (.875)^4\right]$

$Q_w = .952$

Torsional Shear Stress $S_{st} = \dfrac{M_t}{Q_w} = \dfrac{3069}{.952} = 3224$ psi

Combined Shear Stress (direct & torsion) $= 1209 + 3224 = 4423$ psi

Using AISI 1020 HRS mtg. plate and ASTM A276 Type 304 stainless steel shaft, and assuming that the weld properties will equal those of the parent metals:

Min. Tensile Yield = 30,000 psi (stain. stl.)

Max. Allowable Direct Shear = 60% yield = 18,000 psi

Max. Allowable Torsional Shear = 65% yield = 19,500 psi

Therefore, since the direct shear of 1209 psi and the torsional shear of 3224 psi are respectfully less than the allowable direct and torsional shear, the materials and welds are adequate for this application.

CASE II-F Carrier Shaft (Ref. Dwg. 2-1026-P28-Rev. B)
- Mat'l.: ASTM A26 Stainless Steel Type 304

The weakest portion of the shaft occurs at its least area which includes the .185" flat for the cap, the .75" dia. bore for the cam follower, and the 3/8 x 3/16" keyway.

Jam Stress Calc. (Ref. Dwg. 2-1026-SC3) per Fig. 11_B

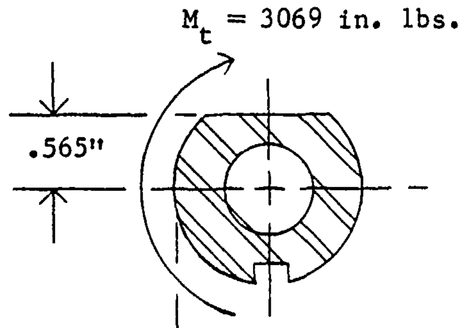


fig 11_A

Carrier Shaft Cross-Section @ Weakest Area

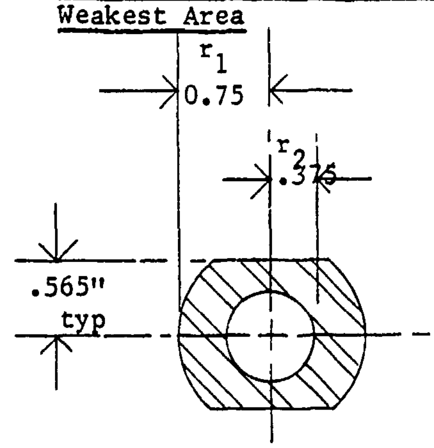


fig. 11_B

Worst Condition

Torsional Section Modulus Q
Ref. Roark's "Formulas for Stress & Strain" pg. 194 and 199 using Case 26 due to its worst condition

$$Q_{\text{carrier shaft}} = Q_{\text{shaft proper}} = Q_{\text{bore}}$$

$$= C \times r_1^3 - \frac{r_2^3}{2}$$

where C = .912 (actually higher)

$$Q = 0.302$$

Torsional Moment M_t = 3069 in. lbs.

Torsional Shear Stress

$$S_{st} = \frac{M_t}{Q} = \frac{3069}{.302}$$

$$= 10,162 \text{ psi}$$

$$\text{Req'd Tensile Yield Stress} = \frac{10,162}{.65}$$

$$= 15,634 \text{ psi}$$

The req'd. tensile yield stress of 15,634 psi is less than the 30,000 psi yield stress of the ASTM A26 Type 304 Stainless Steel Carrier Shaft, therefore, it is adequate for the application.

Shear Stress on Shaft Key S_s
per Fig. 11_C

$$S_s = \frac{M_t}{\text{Shaft Rad} \times (\text{Key W} \times \text{L})}$$

$$= \frac{3069}{.75 \times .375 \times 1.25} = 8730 \text{ psi}$$

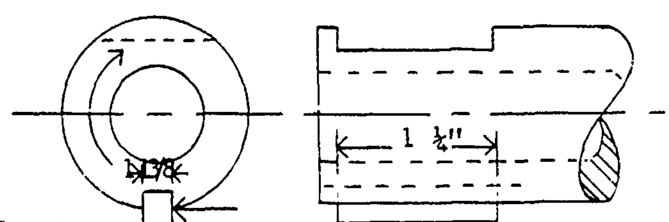


fig 11_C
Shaft Key

Therefore, since the shear stress of 8,730 psi is less than the allowable shear stress of 32,400 psi for AISI 1018 CRS, the 3/8" sq. key is adequate for the application.

Case II-G Guide Arm (Ref. Dwg. 2-1026-P27-Rev. A)

-Mat'l AISI 1018 & 1020 HRS

Jam Stress Calculations (Ref. Dwg. 2-1026-SC3)
Per Fig. 12

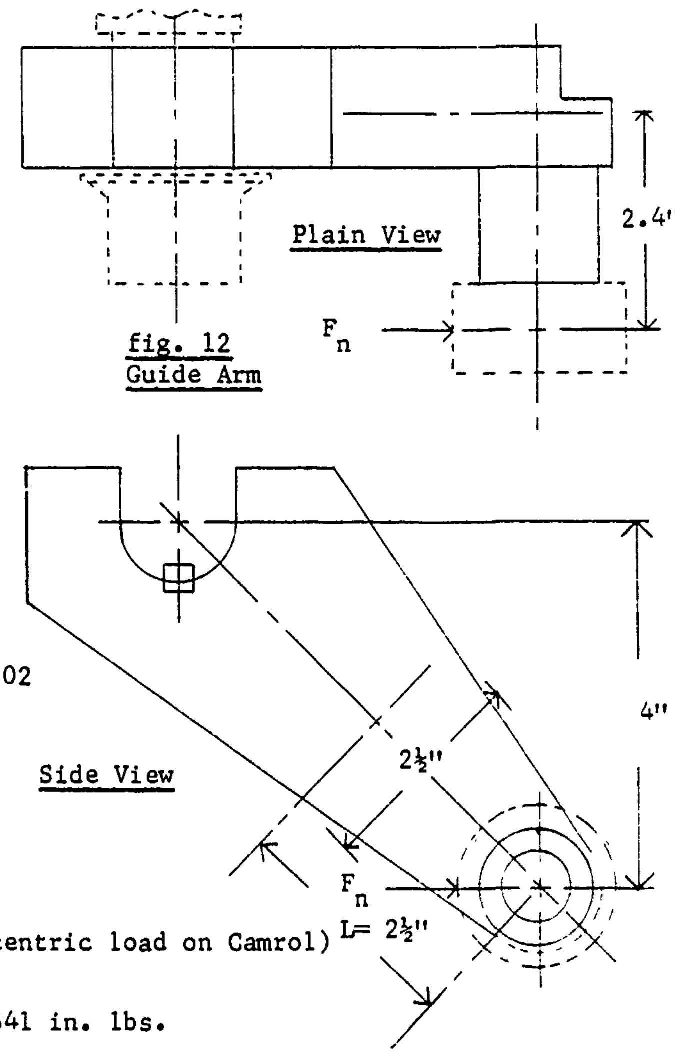


fig. 12
Guide Arm

Normal Force to Resist F_n
Carrier Shaft Torque

$F_n = \frac{M_t}{4} = \frac{3069}{4} = 76.7$

Bending Moment $M_b = F_n \times L$

Assuming the normal force working on the average cross-section of the guide arm (at L = 2.5")

$M_b = 76.7 \times 2.5 = 1918$ in. lbs.

Bending Section Modulus $Z = 1.302$
@ L = 2.5"

Bending Stress $S_b = \frac{M_b}{Z} = \frac{1918}{1.302}$

$= 1473$ psi

Torsional Moment M_t (due to eccentric load on Camrol)

$M_t = F_n \times 2.4 = 76.7 \times 2.4 = 1841$ in. lbs.

Torsional Section Modulus $Z_p = .866$

Torsional Stress $S_t = \frac{M_t}{Z_p} = \frac{1841}{.866} = 2126$ psi

Combined Stress S_n (bending & torsion)

$$S_n = \frac{S_b}{2} + \sqrt{(\tfrac{1}{2} S_b)^2 + (S_t)^2}$$

$$= \frac{1473}{2} + \sqrt{(737)^2 + (2126)^2}$$

$$= 2987 \text{ psi}$$

Max. Shear Stress $= \sqrt{(\tfrac{1}{2} S_b)^2 + (S_t)^2}$

$$= 2250 \text{ psi}$$

Therefore, since the combined stress of 2987 psi is less than the allowable combined stress of 22,400 psi (.7 Y.S.), and the max. shear stress of 2250 psi is less than the allowable shear stress of 19,200 psi, the guide arm proper is adequate for the application.

Case II-H Camrol Mounting Arm Welds (Ref. Dwg. 2-1026-P27-Rev. A) - 1/8" Fillet Welds

Worst Condition: Per Fig. 13A — Assume no compressive assistance from Camrol stud mounting

Bending Moment $M_b = 767 \times 1.25$

$$= 959 \text{ in. lbs.}$$

Section Modulus of the Welds Z_w using throat area (.707 x leg)

$$Z_w = \frac{\pi\left[(R_o)^4 - (r_i)^4\right]}{4 R_o}$$

$$= \frac{\pi\left[(.713)^4 - (.625)^4\right]}{4\,(.713)}$$

$$= .117$$

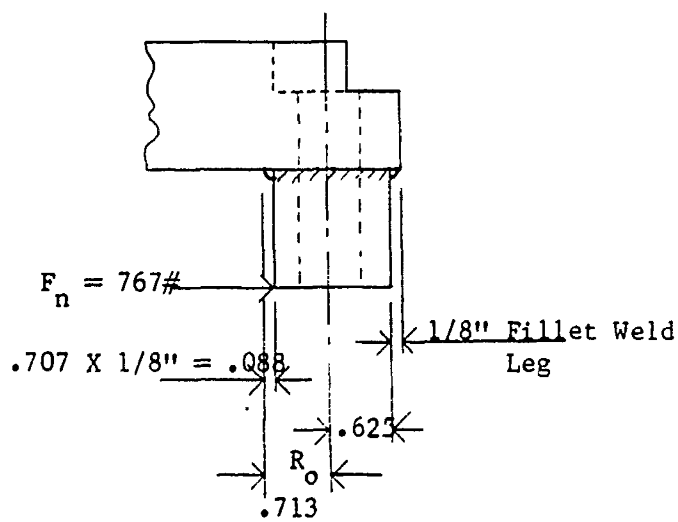


fig 13_A

Camrol Mounting Arm Welds

Weld Shear Stress due to bending $= S_s = \frac{M_b}{Z_w} = \frac{959}{.117} = 8197$ psi

Since the bending shear stress of 8197 psi is less than the allowable direct shear stress of 19,200 psi, the welds are adequate for the application.

Checking Bending Strength of Camrol Mounting Arm
ref. Fig. 13_B

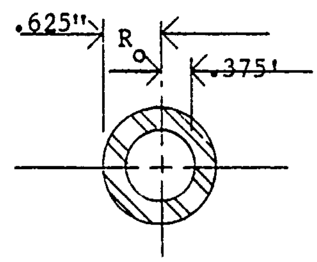


fig 13_B

Camrol Mounting Arm

Section Modulus of Arm Z

$$Z = \frac{(.625)^4 - (.375)^4}{4\ (.625)} = .167$$

Bending Stress mounting arm $S_b = \frac{M_b}{Z} = \frac{959}{.167}$

$= 5743$ psi

Therefore, the Camrol mounting arm is likewise adequate for the application.

Case II-J Cap (Ref. Dwg. 2-1026-47F-Rev. A)

- Mat'l.: AISI 1018 CRS

Worst Condition: Per Fig. 14_A — Assume cap takes entire load (no key)

Carrier Shaft Torque M_t - 3069 in. lbs.

Tangential Force at Point "O" $F_t = \frac{M_t}{rad.} = \frac{3069}{.75}$

$= 4092\#$

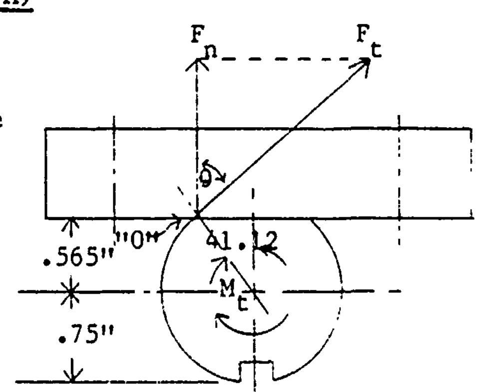


fig 14_A

Cap Loading

$0 = 90^{o} - 41.12^{o} = 48.88^{o}$

<u>Normal Force</u> $F_n = F_t \cos 0$

$= 4092 (\cos 48.88^{o}) = 2691\#$

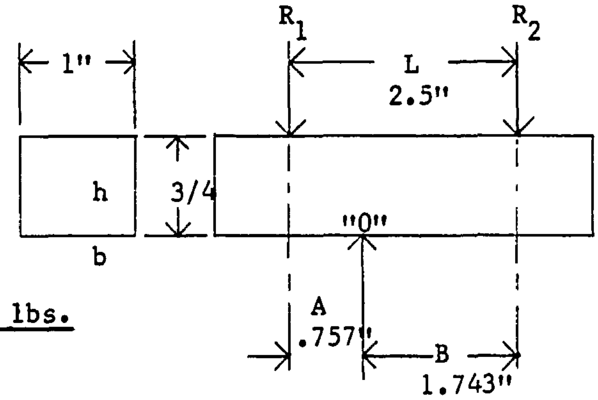
<u>Cap Loading</u>: Ref. Fig. 14B

<u>Bending Moment</u> $M_b = \frac{F_n \ A \times B}{L}$

$= \frac{2691 \times .757 \times 1.743 = 1420 \text{ in. lbs.}}{2.5}$

<u>Cap Section Modulus</u> $Z = \frac{bh^2}{6}$

$= \frac{1 \times (.75)^2}{6} = 0.09375$



<u>fig 14B</u>
<u>Cap Loading</u>

<u>Bending Stress</u> $S_b = \frac{M_b}{Z} = \frac{1420}{0.09375} = 15{,}146$ psi

Since the max. allowable stress for AISI 1018 CRS is 37,800 psi (.7 Y.S.) which is greater than the 15,146 psi bending stress, the cap is acceptable for the application.

<u>Case II-K Cap Mounting Bolts (Item 12 Dwg. 2-1026-P20F-Rev. A)</u>

- Mat'l.: MIL-B-857 Grade 2, ½-13 UNC

<u>Bolt Loading</u>: Per Fig. 14_B Above $R_1 = \frac{2691 \times 1.743}{2.5} = 1876\#$

$R_2 = \frac{2691 \times .757}{2.5} = 815\#$

Therefore, since the min. breaking or stripping force of the ½-13 bolts is 9790#, they are adequate for the application.

Track System Calculations for Jam Condition

NOTE: Stress calculations concerning the track system under jam condition were included in ltems (d) through (h) inclusive, in our letter of transmittal dated October 14, 1976.

Section VII

Engineering Studies and Investigations

This Section contains three Engineering studies conducted by the Contractor during Phase II of R & D Contract No. N00024-72-C-500.

A. Design Study on the Posidyne Clutch/Brake

B. Investigation to Determine if Interal Bracing can be used to Eliminate External Stiffeners on Watertight Trunk Applications for Vertical Stores Conveyors

C. Design Study of Conveyor Overload Protection

DESIGN STUDY ON THE POSIDYNE CLUTCH/BRAKE

DD1423 Item B001AK

(partial fulfillment of line item
004 of Contract N00024-72-C-5500)

Copies: 5

Reproducibles: 0

Submitted to: Commander, Naval Ship Engineering Center
Center Building
Prince George's Center
Hyattsville, Maryland 20782
Code 6164

Attention: Mr. Satterthwaite
Mr. Otto

NOTE: The original of the enclosed DD250 should be signed at destination and destribution made including a signed copy to:

Kornylak Corporation
400 Heaton Street
Hamilton, Ohio 45011

Attention: Mr. R. A. Larson

DESIGN STUDY

ON THE

POSIDYNE CLUTCH/BRAKE

CDRL ITEM B001AK

USN CONTRACT N00024-72-C-5500

JULY 28, 1976

Submitted: July 28, 1976

By: Kornylak Corporation

Hamilton, Ohio

DESIGN CONSIDERATIONS FOR INCORPORATING THE POSIDYNE CLUTCH/BRAKE UNIT INTO THE VERTIFLO POWER TRAIN

JOHN E. GERSTLE

KORNYLAK CORPORATION

SYNOPSIS

The Posidyne Clutch/Brake unit is a versatile tool that offers potential safety to the conveyor system much superior to that of other torque limiting devices. However, in order to utilize this potential for safety, an auxiliary precision air supply must be incorporated and carefully adjusted. A fail-safe mode is inherent in the unit.

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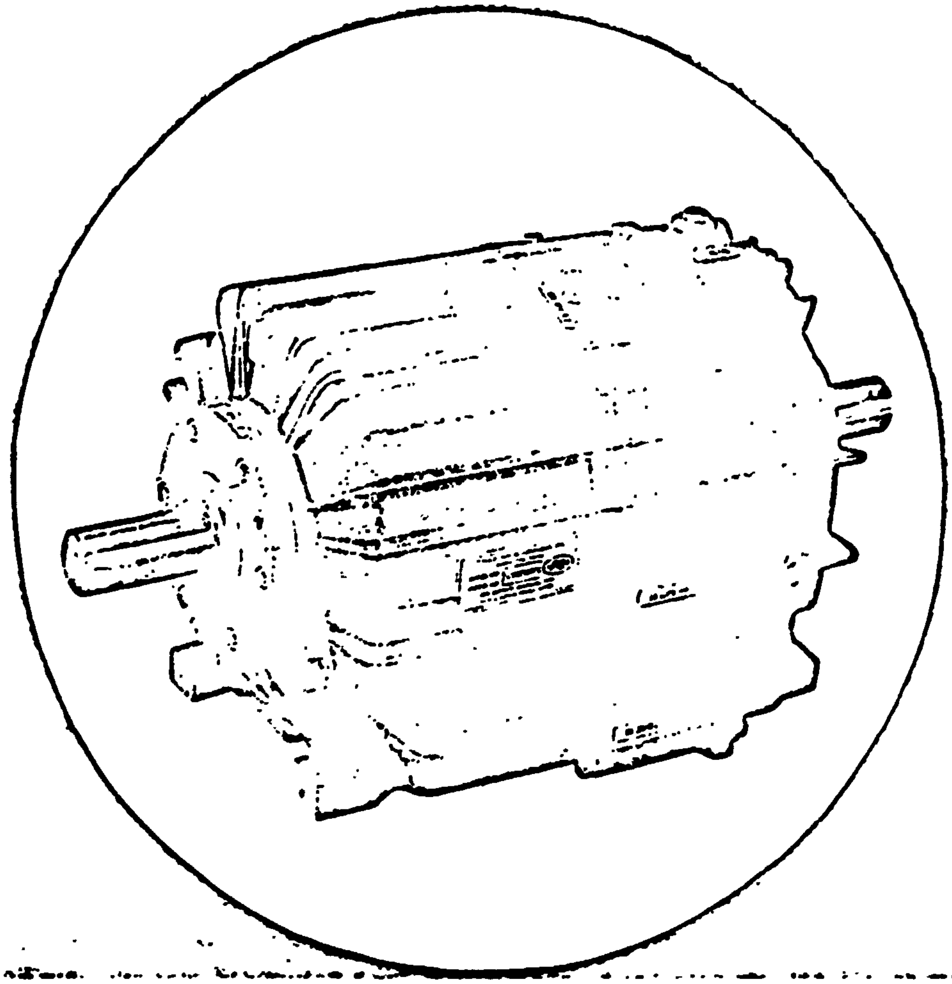
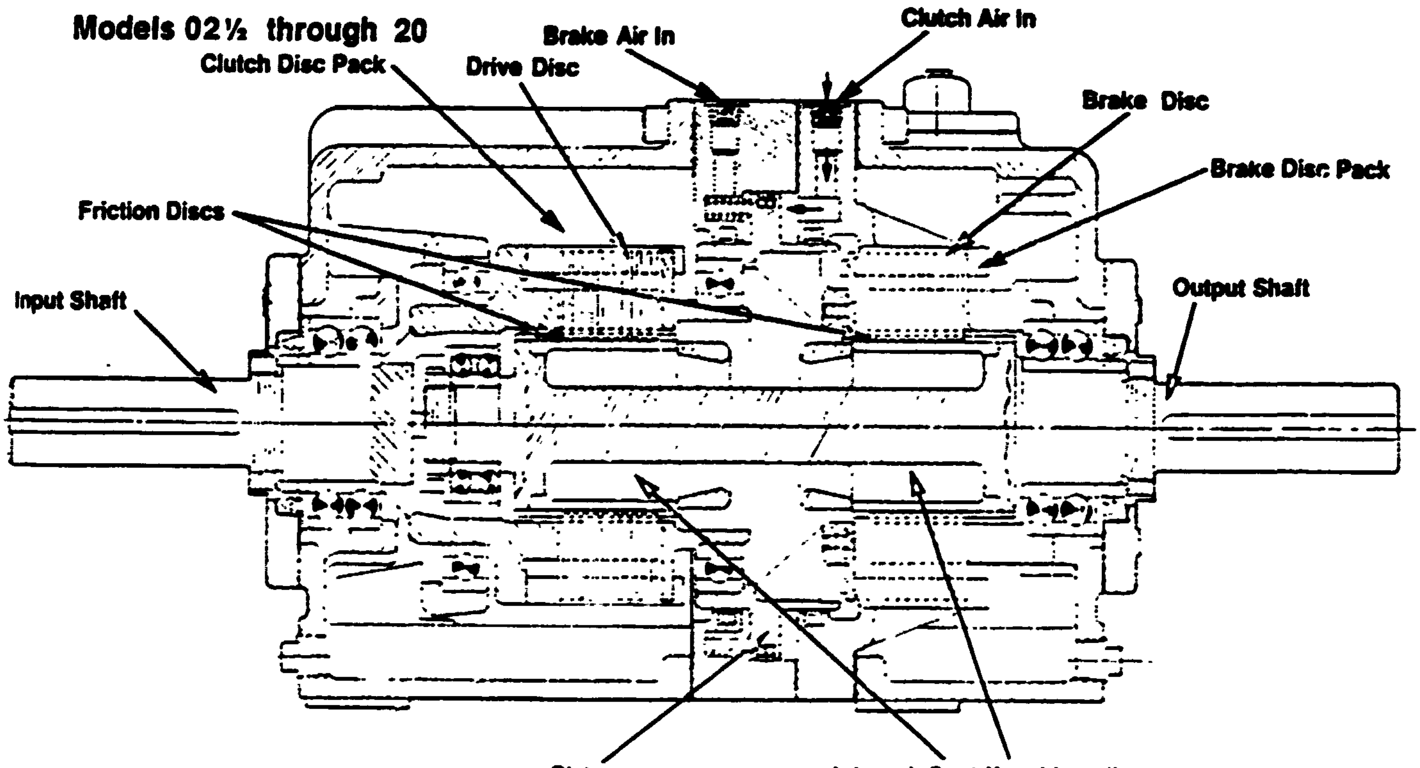


Models 02½ through 20



Patented U.S. Patent =3638773

I. - INTRODUCTION

1.1 Background - Due to the confined nature of the Vertiflo style of conveyor system, jam conditions inevitably arise. The Kornylak Vertiflo has a variety of safety switches to detect misloaded packages before a jam can occur. However, switch failure, or some condition unrelated to the cargo could cause a physical jam of the system.

The immediate result of a jam situation on the conveyor is an instantaneous increase in the torque drawn from the drive train. This is transmitted from the carrier chains to the head sprockets, to the reducer, to the drive clutch, and to the motor. The motor uses extra power to provide the elevated torque requirements. If unrelieved, this extra power will burn out the motor, or the extra torque will destroy some part of the power train to release the tension.

1.2 Existing Safety Features - All Kornylak conveyor drive motors are provided with the motor overcurrent protection devices standard in industry. The Vertiflo conveyors are further protected by instantaneous trip overcurrent relays which are so sensitive that they must be bypassed during startup. Further, various photoelectric and cable switches are installed to check the package orientation on the carrier trays.

Mechanical safety consists of some type of slip clutch which will limit the amount of torque that can be exerted by the motor, and possible installation of easily replaceable "weak links" in the system.

1.3 Limitations of Existing Devices - The standard motor overload is designed to protect the motor and thus responds slowly to brief peaks of excess torque which the motor can stand. Thus the torque could cause excessive damage before this switch shut the system down. On the other hand, the instantaneous trip overcurrent relays, if set to be really effective for jam safety, after trip out on a current surge not directly related to a true jam. A patch of rust in the wrong place could stop the conveyor each time a particular link in the chain passes by.

Mechanical slip clutches suffer from basic inaccuracy, and are limited by start-up requirements. The friction force between two pressure plates can vary drastically due to wear, temperature, humidity, and static versus sliding friction. For ball detent type torque limiters, the setting must be adjusted high enough to allow for start-up and cannot easily be reduced while the conveyor is running. Likewise, a different torque limit could not be provided for the "up" versus "down" motion. Refer to section IV on page 14.

1.4 Advantages of Posidyne - The Posidyne clutch unit reduces these disadvantages. Its torque is directly proportional to the air pressure applied to the unit. Thus, it is only necessary to change the applied pressure following start-up to reduce the torque limit to that for "running" jam protection. The torque limit can be set as accurately as needed using precision air pressure regulators for each torque setting. The environment has much less effect on the torque setting than is the case with a friction clutch, since the Posidyne pressure plates are immersed in oil to maintain uniform conditions. Further, this unit dies not provide the "all or nothing" problem of the ball-detent or instantaneous trip overload torque limiting devices. Instead it continues to provide a limited torque to the load until shut off by a zero-speed switch. This allows it to ride over rough spots and survive voltage surges without stopping the conveyor.

In addition the Posidyne clutch provides a "soft start" capability. The start-up torque can be controlled to provide an acceleration ramp, if desired.

1.5 Disadvantages of the Posidyne Clutch - The chief disadvantage of the unit is the requirement for pressurized air and the extra hardware to control this air. A 3-way valve and a precision pressure regulator and gage are required for each torque setting. Also, to make the conveyor less dependent upon external systems, a small compressor must be linked directly to the drive motor to provide the air to operate the clutch.

Temperature has some effect on the torque setting of the unit due to the viscosity change in the oil inside the clutch unit. This leads to a slight torque change between initial turn on and the steady state level. But this is less variation than exists with a friction clutch exposed to the atmospheric humidity as well as temperature. The temperature change from Arctic to Equatorial operation could be compensated for by readjusting the pressure settings as needed.

The standard unit is built of cast iron, which does not meet Navy specs. However, the manufacturer has an optional ductile iron unit which was designed to meet the specs. when these units were used on other Navy projects. This option adds about $100 to the cost of each unit.

1.6 Conclusions - After studying a large number of types of torque limiting devices, the Posidyne Clutch/Brake system was chosen. This system provides the capability to control all phases of the conveyor operation. Its advantages appear to justify the additional cost involved. Refer to section IV on page 14.

II. - HARDWARE

2.1 Posidyne Unit - The clutch and brake within the Posidyne unit each consists of a series of interleaved pressure discs. For the clutch, half of the discs are keyed to the drive member and the rest to the driven member. For the brake, the discs are keyed to the driven member and to the case respectively. When no pressure is applied to the unit, internal springs hold the brake discs together resisting any rotation of the driven shaft. This provides fail-safe braking. If compressed air is applied to the clutch port, the brake is released as the force of the air overcomes the brake spring tension. When more pressure is applied the clutch discs are pressed together to transmit driving torque. The air pressure, minus the pressure required to release the brake, is linearly proportional to the torque transmission capability of the unit.

If any "slip" occurs within the Clutch/Brake unit, the friction forces generate heat. In this unit a built-in oil pump circulates cooling oil between the discs to keep the rubbing surfaces cool and lubricated. The heat is transfered to the finned case to be dissipated. If the unit is unable to eliminate this heat and the oil gets too hot, a temperature switch will shut down the conveyor to prevent destruction to this unit.

An important advantage of the Posidyne unit is the low maintenance required. The manufacturers has performed routine check out of units in the field and has found negligible wear on the pressure plates after years of service except in a few cases of extremely severe duty cycles. This latter case involved driving a flying shear cutting bar stock, in which the cutting mechanism had to be accelerated to the speed of the bar stock in half a revolution, and decelerated during reset to stop within a fraction of an inch of nominal. A small demonstration/test unit has been alternately starting and stopping for several years and has logged over 18 million cycles with negligible plate wear.

The oil used in the units is a high grade of automotive automatic transmission fluid designed for a 20 year service life and capable of operation over a wide temperature range. So, unless something should cause the oil to leak out, the units should not have to be touched for the life of the conveyor.

On the other hand is the problem of run-in. The surfaces of the plates are such that more torque is output per PSI of air pressure when the plates are new than after some use. In order to provide the precision and repeatability needed, the units must each be cycled until the torque relationship no longer changes. This can be done by the manufacturer for an additional charge.

2.2 Compressor - The pressurized air to operate the clutch unit can be generated by a Gast oil-free air compressor belt driven by the conveyor drive motor itself. This eliminates the conveyor dependency on ship air. The motor and compressor are started when the warning horns sound, and there is plenty of air available by the time the clutch is energized to start the conveyor. Only small quantities of air are required but a constant pressure head must be maintained. The chosen compressor can supply the necessary shot of air for start-up even with the motor at its lowest speed, and can remain dead headed for continuous running.

2.3 Air Filter - Since the quantity of air used is so small, there will not be a large build-up of oil or water in the system. However, removal of water from the clutch unit is difficult and is better handled by minimizing the amount of water taken in. Further, micron sized particles in the air system could reduce the accuracy of the precision pressure regulators. Consequently, a Watts air filter with a water limiting coalescin element and automatic drain will be used with the system.

Oil in the system will not hurt the clutch as will water, and might help the valve operation, but the flow of air is too small to operate an oil mist lubricator. The valves chosen do not need oil.

2.4 Pressure Regulators - Since the only control available of the torque transmission of the clutch is the air pressure provided to the unit, precision pressure regulators must be used. Most important is a high degree of repeatability over the environmental conditions that must be faced. Primarily, this is temperature variations, since the regulators will be installed in an enclosed box for security. Chosen was the Fairchild model 10 which is designed to repeat to a fraction of a PSI under all conditions.

2.5 Precision Gages - Although the pressure and torque are controlled by item 2.4 above, the set-up man needs a true read-out of this pressure. Provided are Helicoid style 410TD test gages with ¼% accuracy and .2 PSI meter sub-divisions. With these the set-up man can fine tune the unit to a fraction of a foot-pound of torque.

2.6 Pressure Selector Valves - Three-way direct operated solenoid air valves are needed to control the selection of which pressure is to be applied to the clutch. These are arranged in a cascade fashion with the "start-up" pressure overriding the others. Consequently, at least two of the three valves must be of "universal" type operation in which pressure can flow both ways. The only other requirement of these valves is for long trouble free life without lubrication (ref. item 2.3). A number of valves are under consideration for this function.

2.7 Locked Enclosure - Since the setting of the pressure regulators is so delicate and critical, adjustments must be made by authorized personnel only. For this reason, the (3) regulators (item 2.5) and the (3) solenoid valves (item 2.6) will be installed inside a locked oiltight enclosure. However, since the pressure regulators must bleed air to maintain their precision, a breather hole will be provided in the bottom of the box with a filter/muffler installed to block entry of dirt or other ojects into the box.

The regulators with gages and the solenoid valves with a terminal strip will be premounted and plumbed on a metal panel insert. This panel can be quickly mounted in the enclosure with

(4) nuts, (2) air lines, and a 4-wire electric cable. If necessary the panel can be just as easily removed for repair without disturbing the air line to the clutch or to the compressor.

If the compressor (item 2.2) is not to be used, another source of clean dry compressed air can be connected to the input fitting to this enclosure, and the system will work in identical fashion.

2.8 Zero Speed Switch - A true jam of the conveyor will cause the system to stop. A zero speed switch can detect this condition and cut the power to the drive motor. This becomes more useful when there is a slip clutch of some type since the motor could go on running until the clutch burns up. In the case of the Posidyne unit, the internal temperature switch would shut down the system before the unit were damaged.

The zero speed switch need not be set to trigger on zero speed but can be adjusted to operate whenever the clutch driven member slows below a pre-set minimum speed. This set speed must be somewhere below the slowest of the speeds on the 3-speed motor. Since the slowest conveyor motor speed is 850 RPM, the zero speed switch could be set to operate below 500 RPM.

In order to avoid shutting off the system during start-up, this switch must be bypassed. A start-up timer shorts across the switch contact for the length of time normally required for the conveyor to get up to speed. Thereafter a jam would operate the switch to shut off the system.

III. - OPERATIONAL PROCEDURES

3.1 Operating Sequence:

a. Operator presses "ON" pushbutton at Master Control Station to provide power to the conveyor controls, and selects the running speed.

b. Operator presses one of the "UP" or "DOWN" pushbuttons to initiate the start sequence.

c. Start delay timer (UTR = up, DTR = down) seals in and begins timing down.

d. Corresponding motor starter is energized to accelerate the motor and air compressor to running speed.

e. Simultaneously, the various warning horns sound to warn personnel to move clear of the conveyor mechanism.

f. At time out of the start delay timer, the horns shut off and the start-up timer is energized.

g. At the same time the UP or DOWN solenoid valve is energized along with the START-UP solenoid valve, to apply pressure to the Posidyne clutch.

h. The Vertiflo conveyor accelerates to speed.

i. At time out of the start-up timer, the START-UP valve is de-energized to drop the clutch pressure back to the jam protection level.

j. Simultaneously the by-pass circuit around the zero speed switch is opened, providing the system with full overload protection.

k. If a jam should occur, torque will rise to the level set on the Posidyne and the clutch will slip, leaving the motor running.

l. As soon as the conveyor slows so that the clutch output drops below 500 RPM, the zero speed switch de-energizes the motor circuit to stop the motor.

m. If the jam occurs during the start-up time delay, the clutch will slip at a higher torque, and then the zero speed switch will shut everything off when the start-up timer times out.

3.2 Clutch Set-Up Procedure (by qualified personnel only) - If the air supply to run the clutch is derived from a compressor powered by the conveyor drive motor, a cut-out switch will be installed in the regulator box to de-energize all of the start-up cycle except the motor itself.

a. Unlock and open the locked pressure regulator box, then turn off the conveyor out-put switch inside.

b. At the nearest control box start the conveyor drive motor and air compressor in either direction. This should provide pressure to the (3) air regulators inside the box. NOTE: If an external air supply is used instead of a compressor, turn this air on and ignore steps a and b.

c. Choose the torque requirements for each of the three operating conditions: start-up, up running and down running.

d. From the table provided, compute the exact air pressure requirements in each case, and adjust the respective regulators until these pressures are available as read on the precision gages provided.

e. Restart the conveyor by turning the cut-off switch on. The horns will sound as usual prior to start-up. Watch the pressure gages to see if there is any shift in pressure as the air valves operate to start the clutch.

f. Close and lock the regulator box.

3.3 Clutch Test Procedure - It is necessary for the conveyor manufacturer at some point to determine the actual torque and corresponding air pressure requirements of the clutch during each phase of the conveyor operation.

a. Start the unloaded conveyor in the DOWN direction at the highest speed, and open the locked pressure regulator box.

b. Turn the pressure on the "down" regulator to zero, the conveyor should stop.

c. Raise the pressure to 22 PSI (or 41 PSI for "B" Model) to release the brake, then slowly raise the pressure until the conveyor is driven in full synchronism with the motor.

d. Repeat step c with a full load riding down on each tray.

e. Take the higher pressure valve from steps c and d, add 2 PSI and adjust the "down" regulator to this valve.

f. Repeat steps b to e with the "up" regulator and the conveyor moving at the highest speed in the UP direction.

g. With the conveyor at the highest speed, start it in the UP direction, with full load on each tray.

h. Measure the time from the shut-off of the horns until the conveyor is at full speed.

i. Determine if this acceleration ramp is acceptable. If not, increase or decrease the pressure on the "start-up" regulator in increments no larger than 1 PSI, and repeat steps g and h.

NOTE: A longer acceleration ramp allows a lower torque setting at lower pressure, and better jam protection on start-up. The start-up timer must be adjusted to agree with this ramp.

j. When the desired acceleration ramp is formed, record this pressure setting as well as the pressures determined in step e, for future reference.

k. Close and lock the regulator box.

IV. - COMPARISON OF METHODS FOR TORQUE LIMITING

There are a number of ways to limit the torque transmitted by the conveyor drive system. Below is a breakdown of the methods showing advantages and disadvantages, and specifically the reason that method was not chosen.

METHOD	ADVANTAGES	DISADVANTAGES	EST. COST OF UNIT & REQD. ACCESSORIES
1. Instantaneous Trip Overcurrent Relay	Inexpensive, quick reacting senses load directly off the motor.	Inertia of motor can produce high torques even after power is snut off separate brake is reqd., closely set cut-off valve may react to transients.	$70 per motor speed, plus cost of brake
2. Adj. Voltage Friction Clutch/Brake	Inexpensive, simple to install, easy to select torque settings, different torque for different situations.	Not very accurate or repeatable on torque setting, firction discs need periodic replacement	$500 for clutch/brake unit and (3) adj. voltage P.S.
3. Adjustable Voltage Magnetic Particle Clutch/Brake	Highly accurate remote setting of torques, virtually no maintenance required.	Unit cannot be mtd. vertically, included brake is not fail-safe and will require a separate spring operated brake which needs maintenance.	$800 for unit & (3) P.S. plus cost of brake
4. Ball Detent Torque Limiter	Instantaneous release of jam tension to free-wheeling condition, single to install, no perepherical accessories required except L.S.	Single torque setting permitted must be high enough to take start-up torque without releasing, reset of the unit is a definite problem, cannot be adjusted while conveyor is running, separate brake required.	$600 for unit plus cost of brake
5. Eddycurrent or Hysteresis Clutch	Highly accurate remote setting of torques, virtually no maintenance reqd., can be mtd. in any position, different torques for each situation.	Expensive, no direct speed lock between motor & conveyor, brake is not fail-safe and will require a separate spring operated brake which needs maintenance.	$2000 plus for clutch & controls, plus cost of separate brake

IV. - COMPARISON OF METHODS FOR TORQUE LIMITING (CONTINUED)

METHOD	ADVANTAGES	DISADVANTAGES	EST. COST OF UNIT & REQD. ACCESSORIES
6. Hydraulic/fluid Coupling	Single simple to install unit, low maintenance requirements.	Inaccurate, difficult to adjust, expensive for what it does, no direct speed lock between mtr. and load, requires separate brake.	$1000, plus cost of brake.
7. Air Actuated Friction Clutch/Brake	Simple to install, easy to select torque settings, different torque for different situations.	Not very accurate or repeatable on torque sitting, friction discs need periodic replacement, air supply and controlling accessories required, air needed to apply brake or separate brake required.	$600 for unit, plus $400 for accessories.
8. Posidyne Oil-bathed Friction Disc Clutch/ Brake	Simple to install, easy to remotely select torque, different torque for different situations, virtually no maintenance required, quick reacting, can be mtd. in any position. fail-safe braking.	Air supply and controlling accessories required, extra cost for vertical mount, expensive to some extent.	$1000 for unit plus $400 for accessories.

NOTE: All methods except #1 require some switch to detect the slip or zero speed condition to shut-off the drive motor.

TORQUE LIMITIN METHOD DESIREABILITY EVALUATION

Rating 0 - 1 = Ideal   2 - 3 = Acceptable   4 = Undesirable

	COST							EFFECTIVENESS					USEFULLNESS					
	UNIT ITSELF	ADDITIONAL BRAKE REQUIRED	ACCESSORIES REQUIRED	INSTALLATION	MOUNTING POSITION	SIZE OF UNIT AND ACCESSORIES	POWER REQUIREMENTS	ACCURACY AND REPEATABILITY	MULTIPLE SETTINGS FOR DIF. SITUATIONS	FAIL-SAFE BRAKING	REACTION TO JAM CONDITION	PROTECTION OFFERED FROM JAM	EASE OF SETTING TORQUE(S)	ABILITY TO SET TORQUE DURING RUNNING (remote)	MAINTENANCE REQUIRED	INDICATION OF TORQUE SETTING	RECOVERY FROM JAM SITUATION	TOTAL
Instantaneous Trip Overcurrent Relay(s)	1	3	1	1	0	1	0	2	3	4	2	2	1	1	1	3	2	28
Adjustable Voltage Friction Clutch/Brake	2	1	2	2	1	2	2	3	2	1	1	2	1	1	3	3	1	28
Adjustable Voltage Magnetic Particle Clutch	2	2	2	3	4	2	2	1	2	3	1	1	1	1	1	2	1	30
Ball-Detent Torque Limiter	2	3	0	1	1	1	0	3	4	4	1	1	3	4	2	4	4	38
Eddy-Current or Hysteresis Clutch/Brake	4	2	3	3	1	2	2	1	2	3	1	1	1	1	1	2	1	31
Hydraulic or Fluid Coupling	3	3	3	3	4	3	1	3	4	4	1	2	3	4	3	4	1	46
Air Actuated Friction Clutch/Brake	2	2	3	3	1	3	2	2	2	3	1	2	1	1	3	2	1	33
Posidyne Oil-Bathed Friction Disc Clutch/Brake	3	1	3	3	2	3	2	1	2	1	1	1	1	1	1	1	1	28

V. - CONCLUSION

Since jams are a serious problem with conveyor of this type, it is important to use the best available system to protect against the effects of a jam. A thorough study of the various torque limiting devices on the market leads to the conclusion that the one chosen, Posidyne, offers the best all around capabilities. Its advantages outweigh its disadvantages.

The operational and maintenance requirements of the chosen clutch/ brake system are no worse than those of the current system, and could offer some improvement. Every part of the system is chosen to minimize maintenance requirements. The compressor V-Belt is the only item which may require regular maintenance; the clutch pressure plates should never need replacement.

The unit not only offers automatic torque selection for the different phases of operation, but set-up of the torque levels is much easier than adjusting the spring tension on a standard friction or ball-detent clutch.

INVESTIGATION TO DETERMINE IF INTERNAL BRACING CAN BE USED TO ELIMINATE EXTERNAL STIFFENERS ON WATERTIGHT TRUNK APPLICATIONS FOR VERTICAL STORES CONVEYORS

USN CONTRACT NUMBER N00024-72-C-5500
PARTIAL FULFILLMENT OF LINE ITEM 0004:
CDRL ITEM B001AK

Submitted: November 9, 1976

By: Kornylak Corporation
Hamilton, Ohio 45011

TRUNK REDESIGN STUDY

CONTRACT NO. N00024-72-C-5500

DIRECTED BY DESIGN REVIEW MEETING

REF. PARAGRAPH 12, MINUTES OF 22 JUNE 1976 MEETING

TO DETERMINE IF INTERNAL BRACING
CAN BE INCREASED TO ELIMINATE EXTERNAL
STIFFENERS ON WATERTIGHT TRUNK APPLICATIONS

CONTENTS

SECTION I

SIDE PANEL STUDY

A study of the side panel in an effort to eliminate the outside stiffeners by increasing the thickness of the hat section and adding a 3/8 thick rib in place of the shield support.

Reference Drawing:

Panel sizing with stiffeners 2-1026-SC9

Sheet 2 of 2 Rev. B

CALCULATIONS ARE BASED ON THE FOLLOWING

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DDS 1100-4
APPENDIX B

I GENERAL FORMULAE FOR BEAMS WITH A UNIFORMLY VARYING LOAD (SIMPLER FORMULAE FOR DIRECT APPLICATION TO BULKHEAD STIFFENERS ARE STATED LATER)

(a) BEAM FIXED AT BOTH ENDS

R_0 = REACTION AT 0.
R_1 = REACTION AT 1.
M_0 = BENDING MOMENT AT 0.
M_1 = BENDING MOMENT AT 1.
w_0 = LOAD PER UNIT OF LENGTH AT 0.
w_1 = LOAD PER UNIT OF LENGTH AT 1.

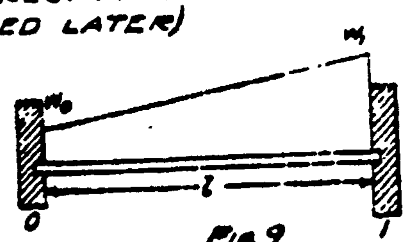


FIG 9

17

DDS 1100-4
APPENDIX B

(c) SIMPLY SUPPORTED BEAMS

$R_0 = -\frac{l}{6}(2w_0 + w_1)$; $R_1 = -\frac{l}{6}(w_0 + 2w_1)$

$F = R_0 + w_0 x + \frac{(w_1 - w_0)x^2}{2l}$

$M = R_0 x + \frac{w_0 x^2}{2} + \frac{(w_1 - w_0)x^3}{6l}$

M_{max} OCCURS WHEN

$x = \frac{l}{w_1 - w_0}\left[-w_0 + \sqrt{\frac{w_1^2 + w_1 w_0 + w_0^2}{3}}\right]$

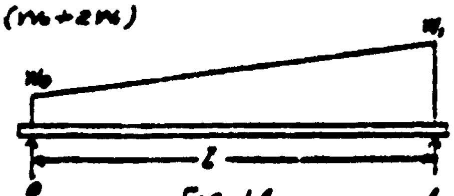


FIG. 14

362 STRENGTH OF MATERIALS

Moment of Inertia of Built-up Sections. — The usual method of calculating the moment of inertia of a built-up section involves the calculations of the moment of inertia for each element of the section about its own neutral axis, and the transferring of this moment of inertia to the previously found neutral axis of the whole built-up section. A much simpler method that can be used in the case of any section which can be divided into rectangular elements bounded by lines parallel

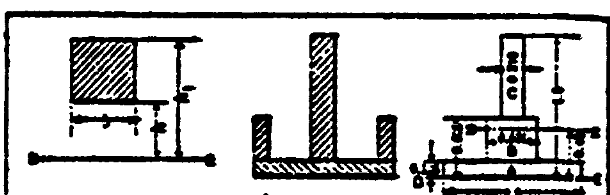


Fig. 1 Fig. 2 Fig. 3

and perpendicular to the neutral axis is the so-called tabular method based upon the formula: $I = \frac{b(h_1^3 - h^3)}{3}$ in which I = the moment of inertia about axis DE, Fig. 1, and b, h and h_1 are dimensions as given in the same illustration.

The method may be illustrated by applying it to the section shown in Fig. 2 and for simplicity of calculation shown "moved" in Fig. 3. The calculation may then be tabulated as shown in the accompanying table. The distance from the axis DE to the neutral axis xx (which will be designated as d) is found by dividing the sum of the geometrical moments by the area. The moment of inertia about the neutral axis is then found in the usual way by subtracting the area multiplied by d^2 from the moment of inertia about the axis DE.

Tabulated Calculation of Moment of Inertia

Section	Breadth b	Height h_1	Area $b(h_1 - h)$	h_1^2	Moment $\frac{b(h_1^2 - h^2)}{2}$	h_1^3	I about axis DE $\frac{b(h_1^3 - h^3)}{3}$
A	1.500	0.125	0.187	0.016	[illegible]	[illegible]	[illegible]
B	0.531	0.625	0.266	0.391	[illegible]	0.244	[illegible]
C	0.229	1.500	0.191	2.250	0.203	3.375	[illegible]
			$A = 0.644$		$M = 0.315$		$I_{DE} = 0.372$

The distance d from DE, the axis through the base of the configuration, to the neutral axis xx is:

$$d = \frac{M}{A} = \frac{0.315}{0.644} = 0.49$$

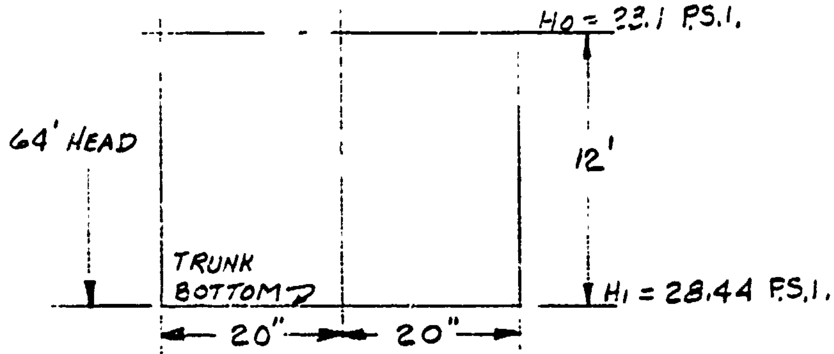
The moment of inertia of the entire section with reference to the neutral axis xx:

$$I_N = I_{DE} - Ad^2$$
$$= 0.372 - 0.644 \times 0.49^2$$
$$= 0.217$$

S = Max. Allowable Stress = 27,000 (Per Gen. Spec. for Ships of USN Section 100, Pg. 2, Line 25)

Use 60t for effective plate width or stiffener spacing, whichever is less. (Per DDS,1100-3-e)

HEAD PRESSURE FROM 28.44 to 23.1 P.S.I.



$W_o = 23.1 \times 20 = 462$, $w_1 = 28.44 \times 20 = 568.8$#/in. of length

$$X = \frac{144}{106.8}\left[-462 + \sqrt{\frac{568.8^2 + (568.8 \times 462) + 462^2}{3}}\right] = 73.24 \text{ in.}$$

$$R_o = \frac{144}{6}(2 \times 462 + 568.8) = 35827.2 \text{ in. lbs.}$$

$$M = 35827.2 \times 73.24 - \frac{462 \times 73.24^2}{2} - \frac{106.8 \times 73.24^3}{864} = 1336678.8 \text{ in. lbs.}$$

Z reqd. $= \frac{1336678.8}{27000} = \underline{\underline{49.5}}$ in.^{3} for the above condition with one vertical stiffener at 20" location

With a horiz. stiffener located at 6'-0" above the base along with a vert. stiffener at 20", the sec. mod. can be reduced as indicated below.

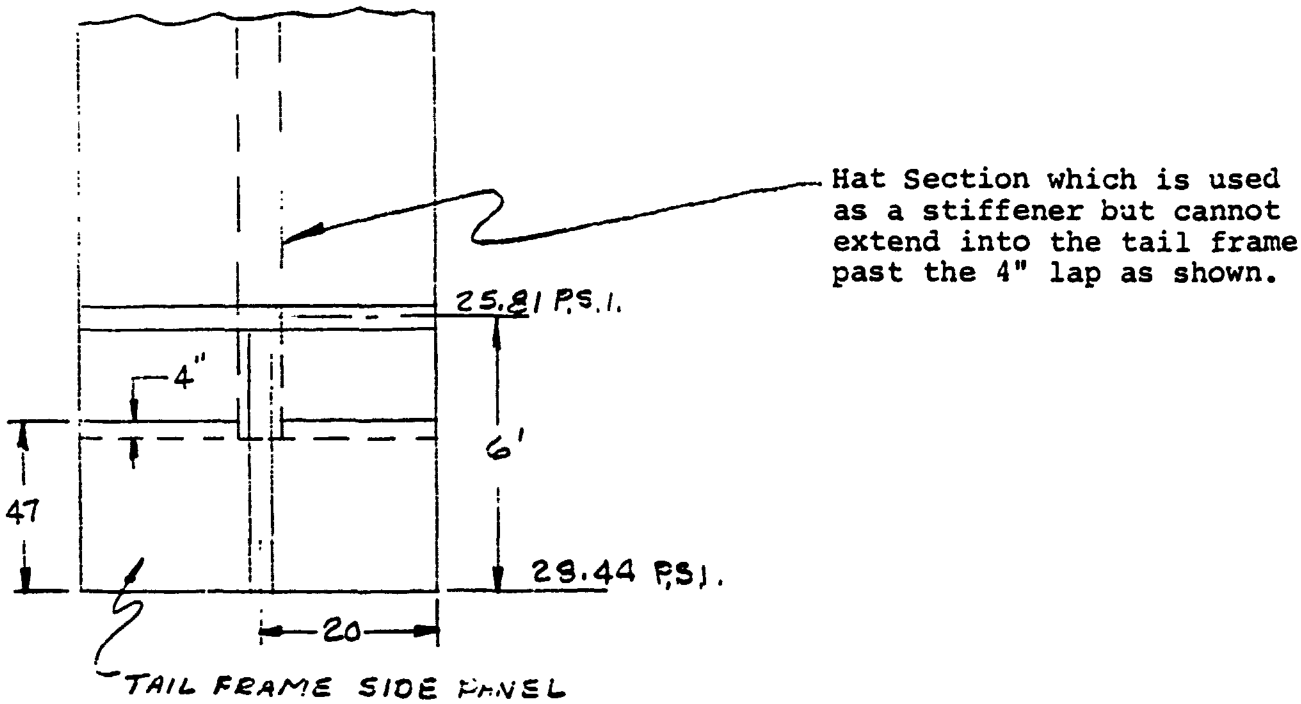
$$X = \frac{72}{52.6}\left[-516.2 + \sqrt{\frac{568.8^2 + (568.8 \times 516.2) \times 516.2^2}{2}}\right] = 36.29$$

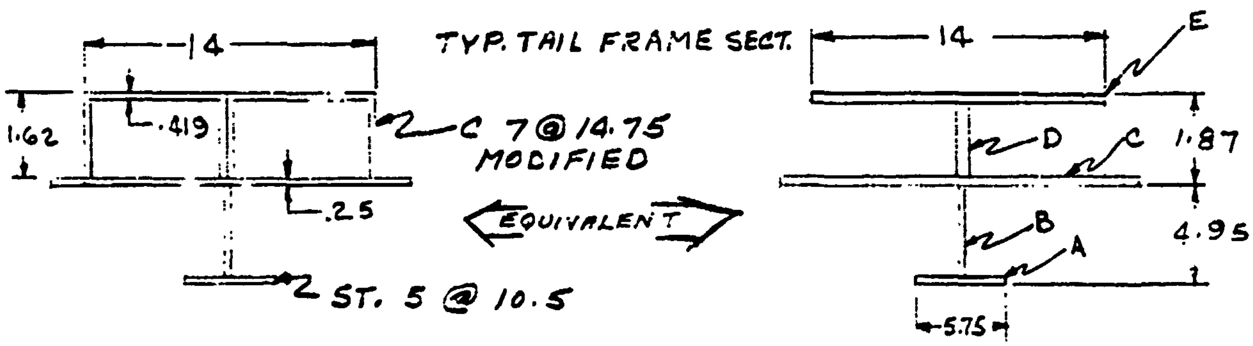
$$R_o = \frac{72}{6}(2 \times 516.2 + 568.8) = 19214.4 \text{ in. lbs.}$$

$$M = 19214.4 \times 36.29 - \frac{516.2 \times 36.29^2}{2} - \frac{52.6 \times 36.29^3}{432} = 351562.95 \text{ in. lbs.}$$

Z reqd. $= \frac{351562.95}{27000} = \underline{\underline{13.02}}$ in.^{3} at tail frame side panel

HEAD PRESSURE FROM 28.44 TO 25.81 PSI



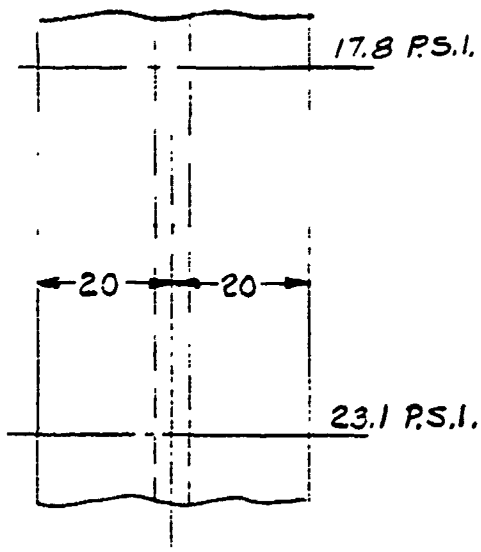


SEC	b	h_1	A	h_1^2	M	h_1^3	IDE
A	5.75	.34	1.95	.12	.34	.04	.076
B	.24	4.95	1.11	24.5	2.92	121.28	9.70
C	15	5.2	3.75	27.04	19.05	140.61	96.65
D	1.67	6.4	2.0	40.96	11.62	262.14	67.65
E	14	6.82	5.86	46.51	38.85	317.22	257.04
			14.67		72.78		431.11

$d = \frac{72.78}{14.67} = 4.96$ $\quad I_n = 431.11 - 14.67 \times 4.96 = 70.20$

$Z = 14.15 \text{ in.}^3$ This exceeds 13.02 in.^{3} reqd., Ref. Pg. 3

HEAD PRESSURE FROM 23.1 TO 17.8 PSI



$w_o = 17.8 \times 20 = 356,\ w_1 = 23.1 \times 20 = 462$

$$X = \frac{144}{106}\left(-356 + \sqrt{\frac{462^2 + (462 \times 356) + 356^2}{3}}\right) = 73.55$$

$$R_o = \frac{144}{6}(2 \times 356 + 462) = 28176$$

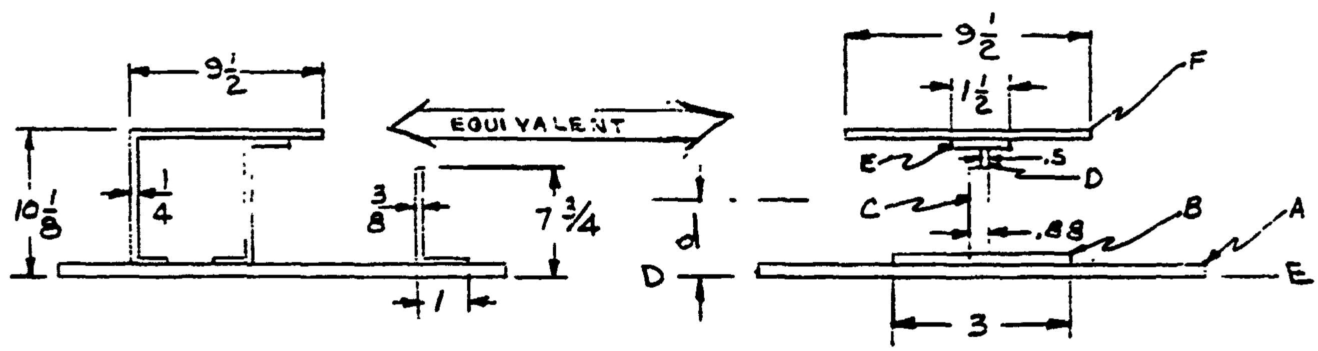
$$M = 28176 \times 73.55 - \frac{356 \times 73.55^2}{2} - \frac{106 \times 73.55^2}{864} = 998708.8$$

Z Required = 36.98 in.^{3} This is the maximum Z required. For the side panel use hat section as stiffener and increase plate thickness to 1/4" and add a 3/8 thick rib in place of the shield support.

See next page for increased hat section calculations.

Revised Hat Section

Increase material thickness from 3/16" to 1/4". Add new 3/8 thick continuous rib at front shield location.



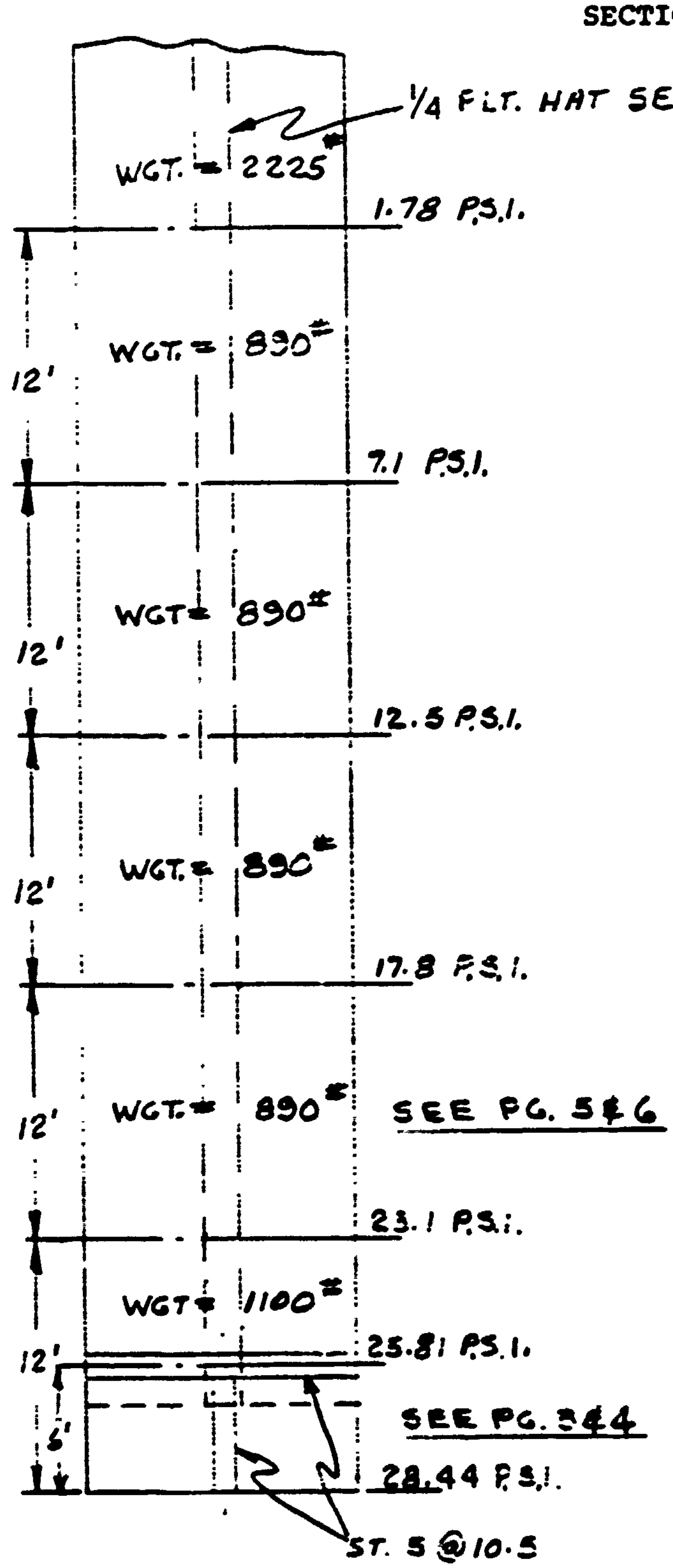
SEC.	b	h_1	A	hi_2	M	$h_1{}^3$	IDE.
A	15	.25	3.75	.062	.46	.015	.075
B	3	.5	.75	.25	.28	.125	.11
C	.88	7.75	6.38	60.06	26.31	465.48	136.5
D	.5	9.38	.81	87.98	6.98	825.29	59.96
E	1.5	9.87	.31	97.42	5.9	961.5	68.11
F	9.5	10.12	2.38	102.41	23.7	1036.43	237.28
			14.38		63.63		502.03

$d = \frac{63.63}{14.38} = 4.42$ 5.69

In. = 502.03 - 14.38 x 4.42^2 = 221.1

Z = 38.85 in.^{3},

This exceeds 36.98 in.^{3} required, reference Page 5



Typ. trunk side panel. The maximum span of a panel will be 12'. A horizontal stiffener should be at each span unless a deck is at this location.

The bottom 12' panel will require a horizontal and vertical stiffener as shown.

Panel plate thickness will be 1/4 throughout the length of the trunk.

Total weight = 6885 lbs. per side

SECTION I

CONCLUSION

The outside vertical side panel stiffeners can be eliminated by doing the following:

1. Adding horizontal and vertical stiffeners to the bottom panel since the hat section cannot extend into the tail frame. See Pg. 3 & 4.

2. Increasing the thickness of the hat section from 3/16 to ¼ and adding a 3/8 thk. rib in place of the shield support.

SECTION II

FRONT & REAR PANEL STUDY

A. STUDY OF THE TRUNK FRONT AND REAR PANEL IN AN EFFORT TO REDUCE THE SIZE & WEIGHT OF THE PANEL TO A MINIMUM WITH STIFFENERS AND MAKE THE PANEL MORE UNIFORM IN CROSS-SECTION. THIS CAN BE DONE BY ADDING HORIZONTAL AS WELL AS VERTICAL STIFFENERS TO EITHER THE INTERNAL OR THE EXTERNAL SURFACE OF THE REAR PANEL AND THE EXTERNAL SURFACE OF THE FRONT PANEL AS REQUIRED.

REF. DWG. PANEL SIZING WITH STIFFENERS 2-1026-SC 9

CALCULATIONS ARE BASED ON THE FOLLOWING

12 DDS 1100-4 APPENDIX B

I GENERAL FORMULAE FOR BEAMS WITH A UNIFORMLY VARYING LOAD. (SIMPLER FORMULAE FOR DIRECT APPLICATION TO BULKHEAD STIFFENERS ARE STATED LATER)

(a) BEAM FIXED AT BOTH ENDS.

R_0 = REACTION AT 0.

R_1 = REACTION AT 1.

M_0 = BENDING MOMENT AT 0.

M_1 = BENDING MOMENT AT 1.

w_0 = LOAD PER UNIT OF LENGTH AT 0.

w_1 = LOAD PER UNIT OF LENGTH AT 1.

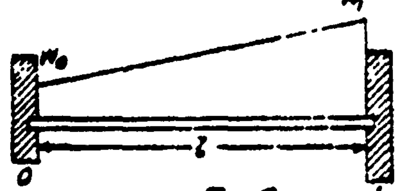


FIG 9

17 DDS 1100-4 APPENDIX B

(c) SIMPLY SUPPORTED BEAMS

$$R_0 = -\frac{l}{6}(2w_0 + w_1) \; ; \quad R_1 = -\frac{l}{6}(w_0 + 2w_1)$$

$$F = R_0 + w_0 x + \frac{(w_1 - w_0)x^2}{2l}$$

$$M = R_0 x + \frac{w_0 x^2}{2} + \frac{(w_1 - w_0)x^3}{6l}$$

M_{max} OCCURS WHEN

$$X = \frac{l}{W_1 - W_0}\left[-W_0 + \sqrt{\frac{W_1^2 + W_1 W_0 + W_0^2}{3}}\right]$$

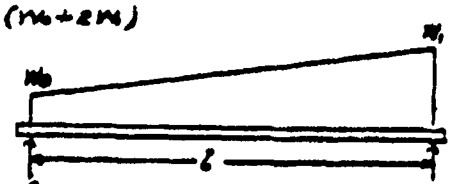


FIG. 14

362 STRENGTH OF MATERIALS

Moment of Inertia of Built-up Sections. — The usual method of calculating the moment of inertia of a built-up section involves the calculations of the moment of inertia for each element of the section about its own neutral axis, and the transferring of this moment of inertia to the previously found neutral axis of the whole built-up section. A much simpler method that can be used in the case of any section which can be divided into rectangular elements bounded by lines parallel

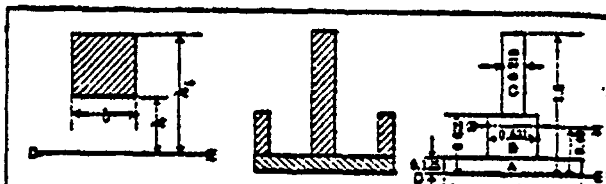


Fig. 1 Fig. 2 Fig. 3

and perpendicular to the neutral axis is the so-called tabular method based upon the formula: $I = \frac{b(h_1^3 - h^3)}{3}$ in which I = the moment of inertia about axis DE, Fig. 1, and b, h and h_1 are dimensions as given in the same illustration.

The method may be illustrated by applying it to the section shown in Fig. 2 and for simplicity of calculation shown "massed" in Fig. 3. The calculation may then be tabulated as shown in the accompanying table. The distance from the axis DE to the neutral axis xx (which will be designated as d) is found by dividing the sum of the geometrical moments by the area. The moment of inertia about the neutral axis is then found in the usual way by subtracting the area multiplied by d^2 from the moment of inertia about the axis DE.

Tabulated Calculation of Moment of Inertia

Section	Breadth b	Height h_1	Area $b(h_1 - h)$	h_1^2	Moment $\frac{b(h_1^2 - h^2)}{2}$	h_1^3	I about axis DE $\frac{b(h_1^3 - h^3)}{3}$
A	1.500	0.125	0.187	0.016	0.012	0.002	0.001
B	0.531	0.625	0.266	0.391	0.100	0.244	0.043
C	0.219	1.500	0.191	2.250	0.203	3.375	0.228
			$A = 0.644$		$M = 0.315$		$I_{DE} = 0.272$

The distance d [illegible] DE, the axis through the base of the configuration, to the neutral axis xx is:

$$d = \frac{M}{A} = \frac{0.315}{0.644} = 0.49$$

The moment of inertia of the entire section with reference to the neutral axis xx is:

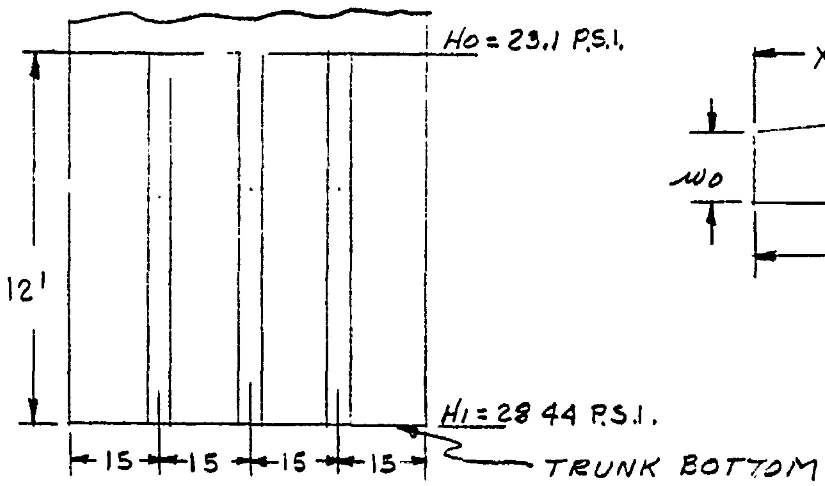
$$I_N = I_{DE} - Ad^2$$
$$= 0.272 - 0.644 \times 0.49^2$$
$$= 0.117$$

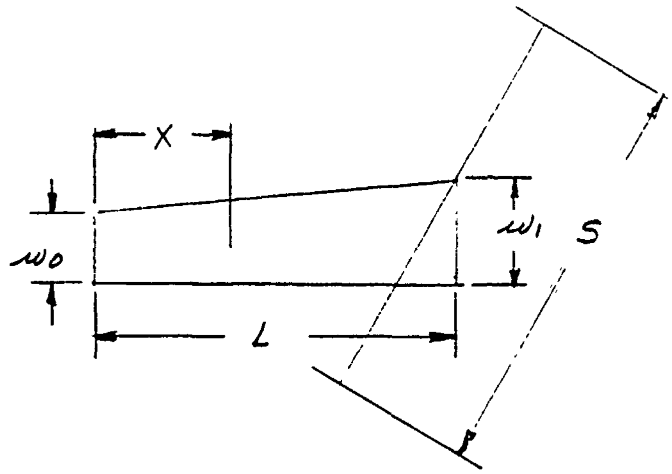
S = Max. Allowable Stress = 27,000 (Per Gen. Spec. for Ships of USN Section 100, Pg. 2, Line 25)

Use 60t for effective plate width or stiffener spacing, whichever is less (Per DDS,1100-3-e)

STIFFENER & PLATE REQUIREMENTS FROM 28.44 TO 23.1 PSI

HEAD PRESSURE





S = Stiffener Spacing = 15"

1 = 144"

Trunk Plating = ½"

Use (60t) for effective width or stiffener spacing (Ref. DDS1100-3-C) whichever is less, in this case 15"

$W_o = H_o \times S = 23.1 \times 15 = 346.5 =$ lbs./in. of length

$w_1 = H_1 \times S = 28.44 \times 15 - 426.6 =$ lbs./in. of length

$$X = \frac{144}{80.1}\left(- 346.5 + \sqrt{\frac{426.6^2 + (426.6 \times 346.5) + 346.5^2}{3}}\right)$$

$X = 1.79 \times 40.74 = 72.44$ in.

$R_o = \frac{144}{6}(2 \times 346.5 + 426.6) = 26870.4$ in. lbs.

$$M = 26870.4 \times 72.44 - \frac{346 \times 72.44^2}{2} - \left(\frac{80.1 \times 72.44^3}{864}\right)$$

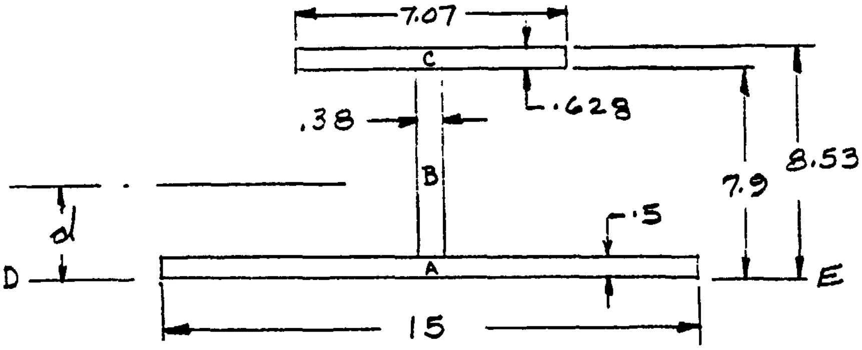
$M = 1946491.7 - 907826.15 - 35241.47$

$M = 1,003,424.2$ in. lbs.

$$Z \text{ Reqd.} = \frac{M}{S} = \frac{1,003424.2}{27,000} = \underline{\underline{37.16}} \text{ in.}^3$$

SECTION II

VERTICAL STIFFENER REQUIREMENTS



SEC	b	h_1	A	h_1^2	M	h_1^3	IDE
A	15	.5	7.5	.25	1.875	.125	.62
B	.38	7.9	2.81	62.41	11.81	493.04	62.44
C	7.07	8.53	4.44	72.76	36.59	620.65	300.73
			14.75		50.27		363.79

$d = \frac{50.27}{14.75} = 3.4 \quad I_n = 363.79 - 14.75 \times 3.4^2 = 193.28$

$Z = \underline{\underline{37.67}}\ in.^3$

This exceeds 37.16 in.^{3} Ref. Pg. 3

Changing the stiffener spacing on Drawing 2-1026-SC9 from 20" to 15" causes the required Z to drop to 37.16 in.^{3}. The stiffeners will change from (2) St. 10 @ 37.5# to (3) St. 8 @ 25#.

The weight per foot of the plate and stiffeners will remain the same.

Wgt. of a ½" thk. x 5' x 12' plate with stiffeners:

Wgt. of Stiffeners = 3 x 25 x 12 = 900

Wgt. of Plate = 102 x 12 = 1224

2124 lbs.

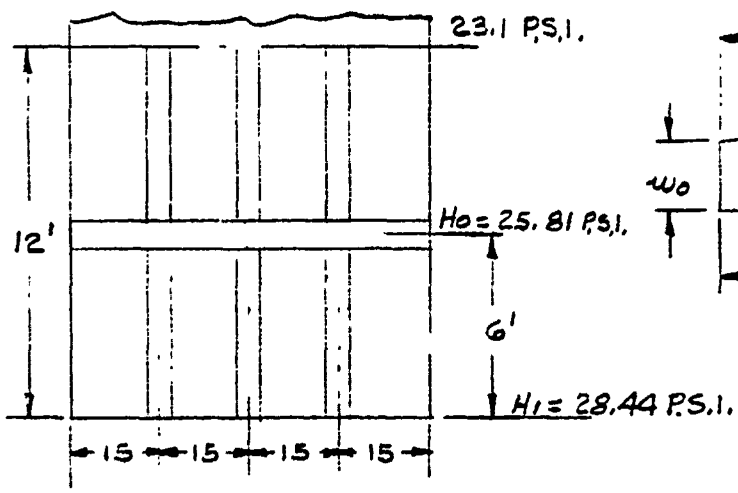
$\frac{2124}{12}$ = 177#/Ft. of Hgt./Side

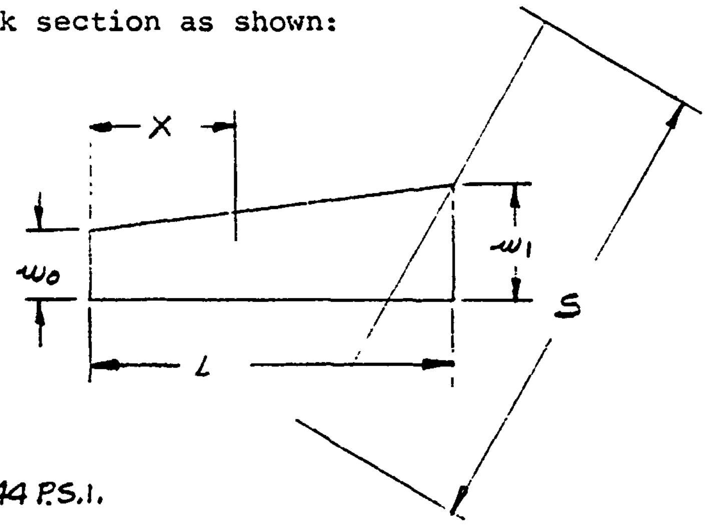
SECTION II

STIFFENER & PLATE REQUIREMENTS

FROM 28.44 TO 25.81 PSI

Add a horizontal stiffener to trunk section as shown:





$S = 15$

$l = 72"$

$w_o = 25.81 \times 15 = 387.15$

$w_1 = 28.44 \times 15 = 426.6$

$$x = \frac{72}{39.45}\left(-387.15 + \sqrt{\frac{426.6^2 + (426.6 \times 387.15) + 387.15^2}{3}}\right)$$

$x = 1.82 \times 19.88 = 36.28$ in.

$R_o = \frac{72}{6}\ (2 \times 387.15 + 426.6) = 14410.8$ in. lbs.

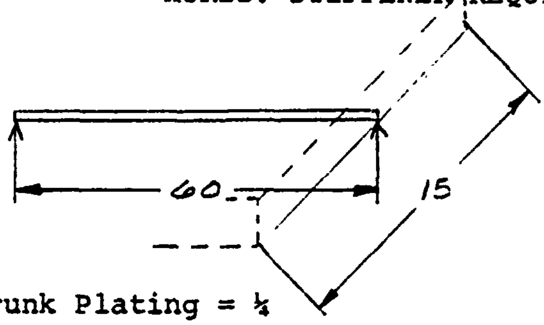
$$M = 14410.8 \times 36.28 - \frac{387.15 \times 36.28^2}{2} - \frac{(39.45 \times 36.28^3)}{432}$$

$522823.82 - 254791.15 - 4360.79$

$M = 263671.88$ in. lbs.

S reqd. $= \frac{M}{S} = \frac{263671.80}{27000} = 9.76$ in.^{3} for vert. stiffeners

HORIZ. STIFFENER REQUIREMENTS (1) REQD.



Trunk Plating = ¼

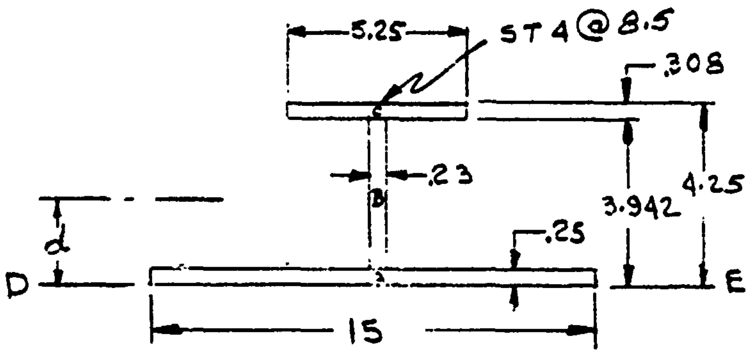
Use 60t fcr effective width of plate with stiffener

60 x ¼ = 15

w = 15 x 25.81 = 387.15

$M = \frac{wl^2}{8} = \frac{387.15 \times 60^2}{8} = 174217.5$ in. lbs.

Z reqd. $= \frac{M}{S} = \frac{174217.5}{27,000} = \underline{\underline{6.45}}$ in.^{3}



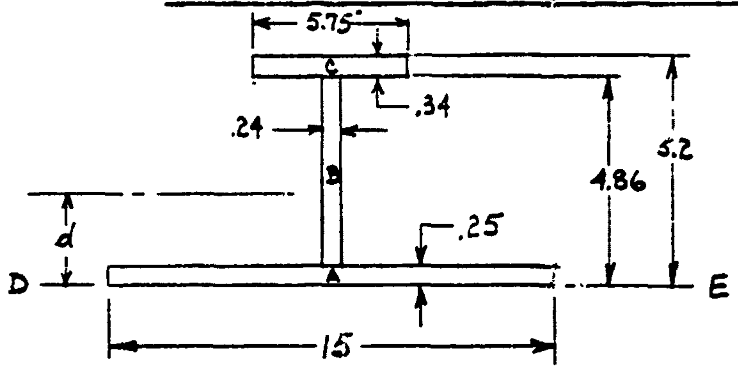
NOTE: USE ST 5 @ 10.5 which is the same stiffener reqd. for vert. stiffener's See Pg. 7

SEC	b	h_1	A	h_1^2	M	h_1^3	IDE
A	15	.25	3.75	.062	.46	.0156	.078
B	.23	3.942	.85	15.54	1.78	61.25	4.69
C	5.25	4.25	1.62	18.06	6.62	76.76	27.14
			6.22		8.86		31.90

$d = \frac{8.86}{6.22} = 1.42$ $\quad I_n = 31.9 - 6.22 \times 1.42^2 = 19.35$ in.^{4}

Z = 6.83 in.^{3} This exceeds 6.45 in.^{3} reqd.

VERTICAL STIFFENER REQUIREMENTS (3) REQD.



SEC	b	h_1	A	h_1^2	M	h_1^3	IDE
A	15	.25	3.75	.062	.46	.0156	.078
B	.24	4.86	1.11	23.62	2.83	114.79	9.18
C	5.75	5.2	1.95	27.04	9.83	140.61	49.49
			6.81		13.12		58.748 in.^{4}

$d = \frac{13.12}{6.81} = 1.93$ $\quad I_n = 58.74 - 6.81 \times 1.93^2 = 33.37$ in.^{4}

Z = 10.2 in.^{3} (9.76 reqd.)

Wgt. of a ¼ x 5' x 12' plate with (3) vert. & (1) horiz. stiffeners:

Wgt. of horiz. stiffener = 5 x 8.5 = 42.5 lbs. (5 x 10.5 = 52.5)

Wgt. of vert. stiffeners = 3 x 10.5 x 12 = 378 lbs.

Wgt. of plate = 51 x 12 = 612 lbs.

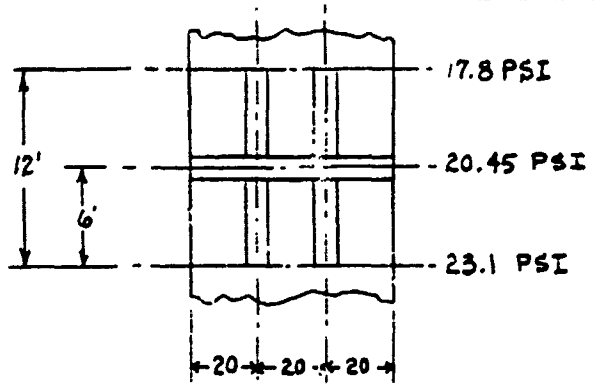
Total Wgt. = 1032.5 lbs.

$\frac{1032.5}{12}$ = 86.04#/ft. of hgt.

86 lb/lin.ft. vs. 177 lb/lin.ft. (Ref. Section II Pg. 4) is a weight savings of 91 lb/lin. ft.

STIFFENER & PLATE REQUIREMENTS

FROM 23.1 TO 20.45 PSI



$w_o = 20.45 \times 20 = 409$ PSI

$w_1 = 23.1 \times 20 = 462$ PSI

$$X = \frac{72}{53}\left(-409 + \sqrt{\frac{462.2^2 + (462.2 \times 409) + 409^2}{3}}\right) = 36.4 \text{ in.}$$

$$R_o = \frac{72}{6}(2 \times 409 + 462) = 15360 \text{ in. lbs.}$$

$$M = 15360 \times 36.4 - \frac{409 \times 36.4^2}{2} - \frac{53 \times 36.4^3}{432}$$

$$= 559104 - 270954.32 - 5916.92$$

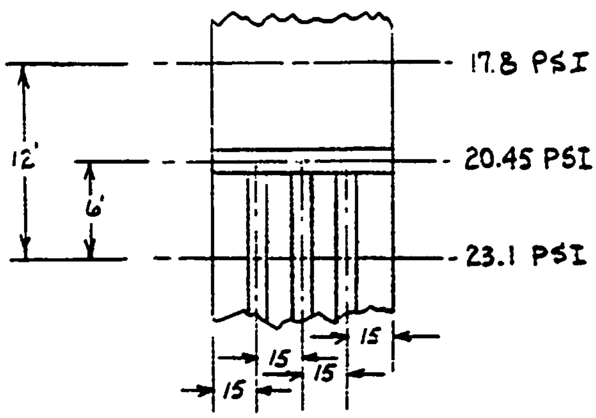
$M = 282232.76$ in. lbs.

Z reqd. = 10.45 in.^3

NOTE: (2) St. 5 @ 10.5 stiffeners from 23.1 PSI to 20.45 PSI have a Z of 10.2 in.^3 per stiffener when a Z of 10.45 is required. Therefore (2) as shown is not strong enough. Run (3) St. 5 @ 10.5 up to 20.45 PSI. See next page for (3) stiffener calculations.

STIFFENER & PLATE REQUIREMENTS

FROM 23.1 TO 20.45 PSI



$w_o = 20.45 \times 15 = 306.75$

$w_1 = 23.1 \times 15 = 346.5$

$$X = \frac{72}{40}\left(-306.75 + \sqrt{\frac{346.5^2 + (346.5 \times 306.75) + 306.75^2}{3}} \right)$$

Z = 36.14 in.

$$R_o = \frac{72}{6}(2 \times 306.75 + 346.5) = 11520 \text{ IN.}$$

$$M = 11520 \times 36.14 - \frac{306.75 \times 36.14^2}{2} - \frac{40 \times 36.14^3}{432}$$

$$= 416332.8 - 200323.1 - 4370.59$$

M = 211639.11 in. lbs.

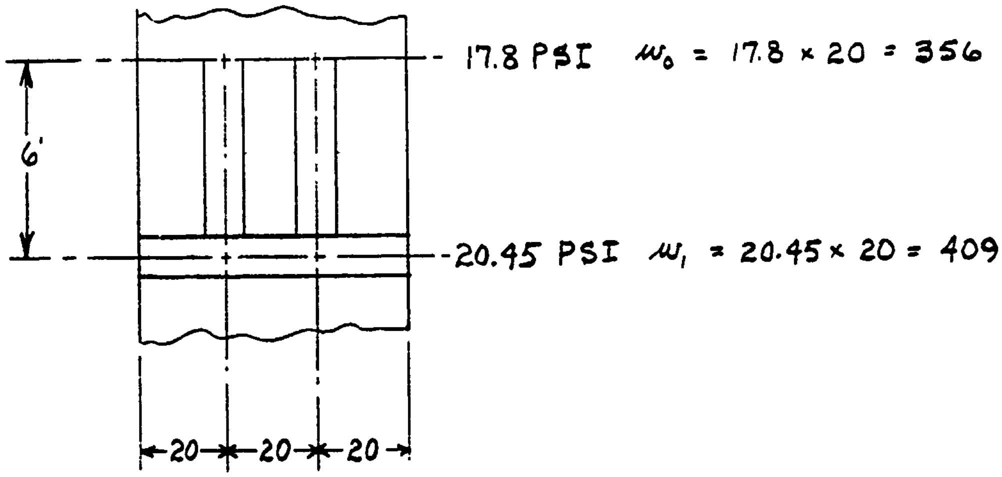
Z reqd. = 7.84 in.^{3} per stiffener

Use (3) St. 5 @ 10.5 with a Z of 10.2 in.^{3}. See Pg. 7.

$S = \frac{M}{Z} = \frac{211639.11}{10.2} = 20748.9$ PSI This is within 27000 PSI allowable stress.

STIFFENER & PLATE REQUIREMENTS

FROM 20.45 TO 17.8 PSI



$$X = \frac{72}{53}\left(-356 + \sqrt{\frac{409^2 + (409 \times 356) + 356^2}{3}}\right) = 36.42 \text{ in.}$$

$$R_o = \frac{72}{6}(2 \times 356 + 409) = 13452 \text{ in. lbs.}$$

$$M = 13452 \times 36.42 - \frac{356 \times 36.42^2}{2} - \frac{53 \times 36.42^3}{462}$$

$$M = 489921.84 - 236102.76 - 5541.8$$

$$M = 248277.28 \text{ in. lbs.}$$

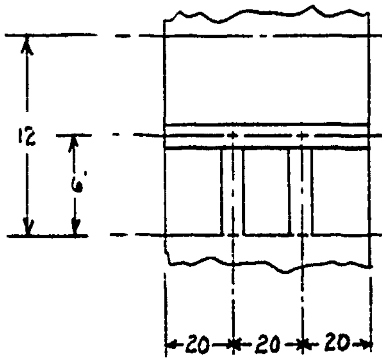
$$Z \text{ reqd.} = \frac{248{,}277.28}{27000} = 9.2 \text{ in.}^3$$

Use (2) St. 5 @ 10.5 with ½ thick plate which gives a Z of 10.2 in.^{3} per Tee, see Pg. 7.

$$S = \frac{248277.28}{10.2} = 24340.9 \text{ PSI (27000 PSI allowable)}$$

STIFFENER & PLATE REQUIREMENTS

FROM 17.8 TO 15.15 PSI



$$X = \frac{72}{53}\left(-303 + \sqrt{\frac{356^2 + (356 \times 303) + 303^2}{3}}\right) = 36.48 \text{ in.}$$

$$R_o = \frac{72}{6}\ (2 \times 303 + 356) = 11544 \text{ in. lbs.}$$

$$M = 11544 \times 36.48 - \frac{303 \times 36.48^2}{2} - \frac{53 \times 36.48^3}{462}$$

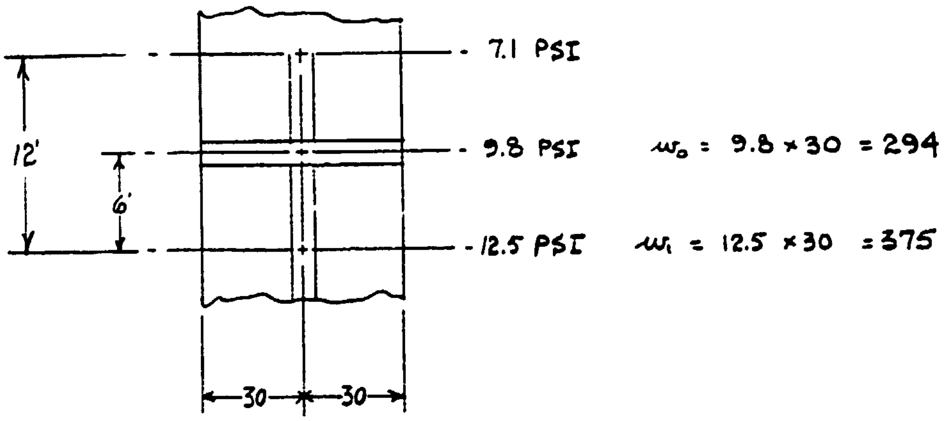
$$M = 421125.12 - 201614.7 - 5569.3 = 213941.12 \text{ in. lbs.}$$

$$Z \text{ reqd.} = \frac{213941.12}{27000} = 7.92 \text{ in.}^3$$

Use (2) St. 5 @ 10.5 with horiz. stiffener, see Pg. 7.

STIFFENER & PLATE REQUIREMENTS

FROM 12.5 TO 9.8 PSI



$$X = \frac{72}{81}\left(-294 + \sqrt{\frac{375^2 + (375 \times 294) + 294^2}{3}}\right) = 36.72 \text{ In.}$$

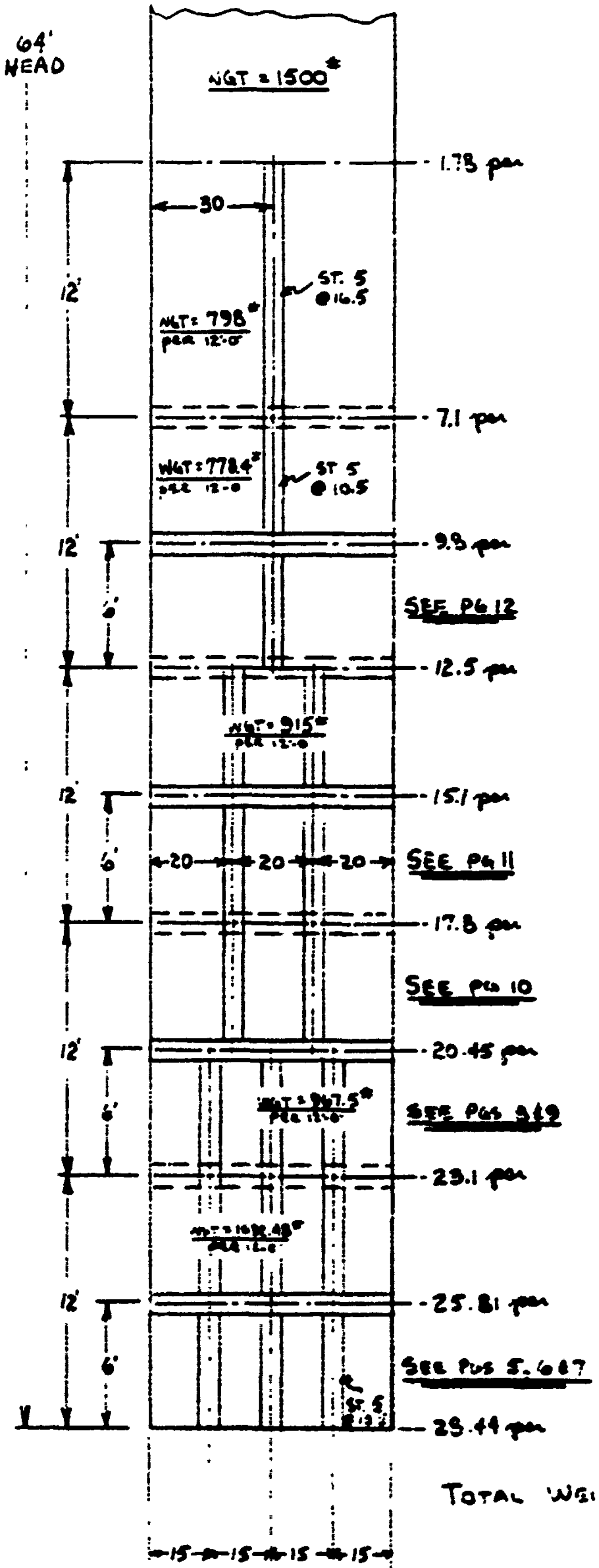
$$R_o - \frac{72}{6}\ (2 \times 294 + 375) = 11556 \text{ in. lbs.}$$

$$M = 11556 \times 36.72 - \frac{294 \times 36.72^2}{2} - \frac{81 \times 36.72^3}{432} = 216844.17 \text{ in. lbs.}$$

$$Z \text{ reqd.} = \frac{216844.17}{27000} = 8.03 \text{ in.}^3$$

Use St. 5 @ 10.5 with ¼ thick plate with a Z of 10.2, see Pg. 7.

$$S = \frac{216844.17}{10.2} = 21259.2 \text{ PSI} \quad (27000 \text{ PSI allowable})$$



Typical trunk showing rear panel arrangement of vertical and horizontal stiffeners with ½ thick plate stiffener arrangement to apply to front panels between door frames as required.

TOTAL WEIGHT = 9991.5# PER SIDE

CONCLUSION

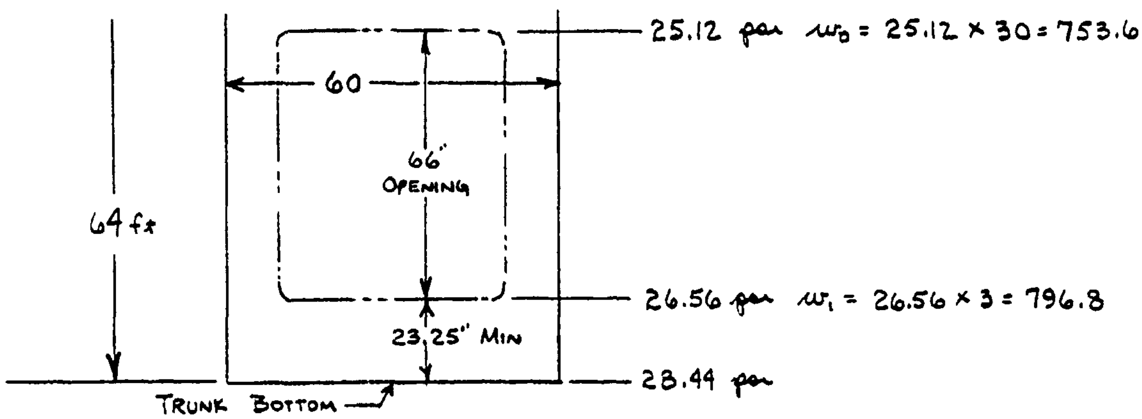
The plate of the trunk panel can be kept at ¼ thick throughout the trunk by adding horizontal and vertical stiffeners as indicated. Except where noted, all stiffeners will be St. 5 @ 10.5. This will enable a nontight trunk to be changed to a watertight trunk with a minimum amount of change.

1. The maximum deck height is 12 foot.
2. Horizontal stiffeners are to be spaced at no more than 6 foot apart except at the deck location where the horizontal stiffener will be eliminated.

At each deck location the vertical stiffeners are to be cutout in the field at installation so that the deck closure material can extend on into the trunk side panel.

DOOR FRAME

Strength of door frame at lowest position on trunk:

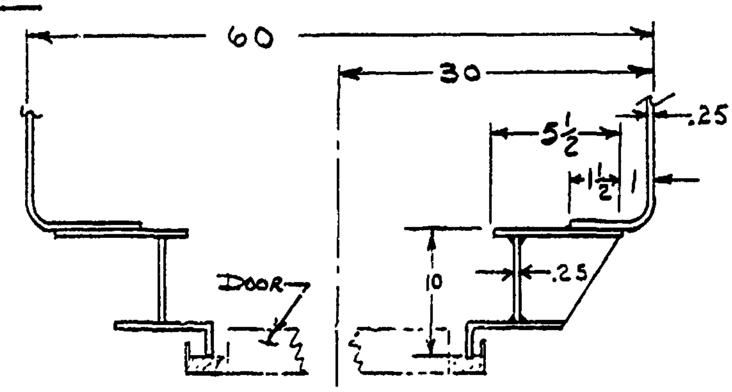


$$X = \frac{66}{43.2}\left(-753.6 + \sqrt{\frac{796.8^2 + (796.8 \times 753.6) + 753.6^2}{3}}\right) = 33.15$$

$$R_0 = \frac{66}{6}\ (2 \times 753.6 + 796.8) = 25344 \text{ in. lbs.}$$

$$M = 25344 \times 33.15 - \frac{753.6 \times 33.15^2}{2} - \frac{43.2 \times 33.15^3}{396} = 422105.5 \text{ in. lbs.}$$

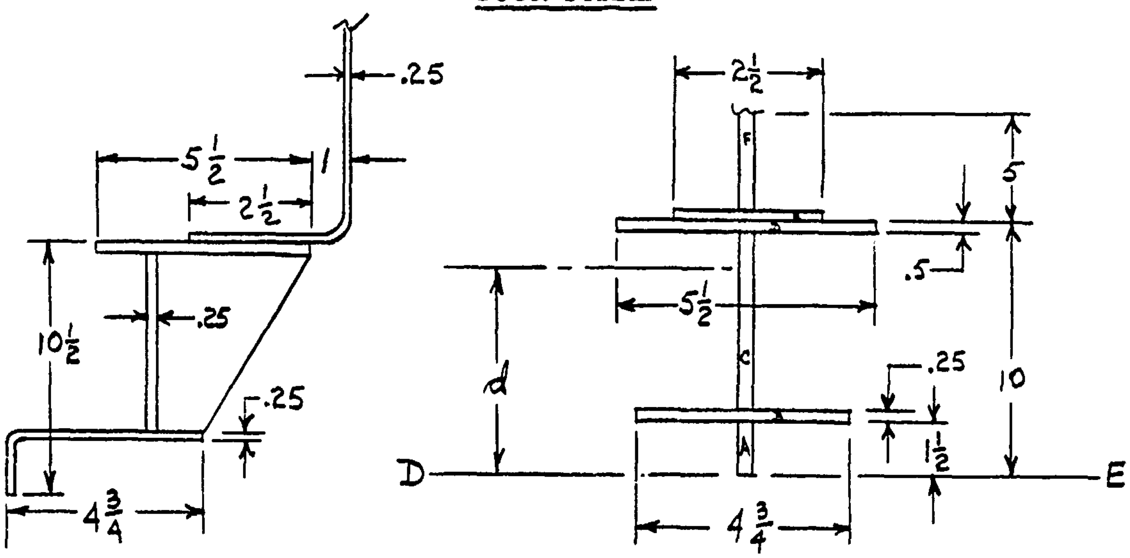
Z reqd. = 15.63 in.^{3}



Typ. Door Frame (Ref. Dwg. 2-1026-117F)

See next page for Frame Sect. calculations.

DOOR FRAME



Assume that the side panel will carry part of the load.

SEC	b	h_1	A	h_1^2	M	h_1^3	IDE
A	.25	1.5	.375	2.25	.28	3.375	.28
B	4.75	1.75	1.187	3.06	1.92	5.35	3.12
C	.25	9.5	1.937	90.25	10.89	857.37	71
D	5.5	10	2.75	100	26.81	1000	261.48
E	2.5	10.25	.62	105.06	6.32	1076.89	64.07
F	.25	15	1.187	225	14.99	3375	191.51
			8.056		61.21		591.46

$d = \frac{M}{A} = \frac{61.21}{8.056} = 7.59$ $I_n = IDE - Ad^2 = 591.46 - 8.056 \times 7.59^2 = 127.37$

$Z = \frac{127.37}{7.59} = 16.78 \text{ in.}^3$ (reqd. = 15.63)

CONCLUSION:

Door frame will withstand the maximum water head on the conveyor.

SECTION III

OPTIONAL SIDE PANEL DESIGN

A study of the conveyor side panel in an effort to keep the thickness and weight of the plate at a minimum.

12 DDS 1100-4
APPENDIX B

I GENERAL FORMULAE FOR BEAMS WITH A UNIFORMLY VARYING LOAD. (SIMPLER FORMULAE FOR DIRECT APPLICATION TO BULKHEAD STIFFENERS ARE STATED LATER)

(a) BEAM FIXED AT BOTH ENDS.

R_0 = REACTION AT 0.
R_1 = REACTION AT 1.
M_0 = BENDING MOMENT AT 0.
M_1 = BENDING MOMENT AT 1.
w_0 = LOAD PER UNIT OF LENGTH AT 0.
w_1 = LOAD PER UNIT OF LENGTH AT 1.

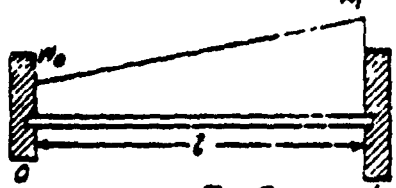


FIG 9

17 DDS 1100-4
APPENDIX B

(c) SIMPLY SUPPORTED BEAMS

$$R_0 = -\frac{l}{6}(2w_0 + w_1)\ ; \quad R_1 = -\frac{l}{6}(w_0 + 2w_1)$$

$$F = R_0 + w_0 x + \frac{(w_1 - w_0)x^2}{2l}$$

$$M = R_0 x + \frac{w_0 x^2}{2} + \frac{(w_1 - w_0)x^3}{6l}$$

M_{MAX} OCCURS WHEN

$$x = \frac{l}{w_1 - w_0}\left[-w_0 + \sqrt{\frac{w_1^2 + w_1 w_0 + w_0^2}{3}}\right]$$

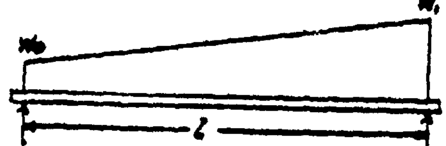


FIG. 14

362 STRENGTH OF MATERIALS

Moment of Inertia of Built-up Sections. — The usual method of calculating the moment of inertia of a built-up section involves the calculations of the moment of inertia for each element of the section about its own neutral axis, and the transferring of this moment of inertia to the previously found neutral axis of the whole built-up section. A much simpler method that can be used in the case of any section which can be divided into rectangular elements bounded by lines parallel

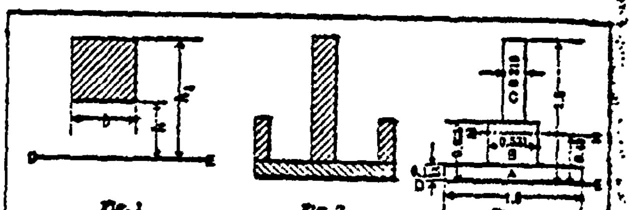


Fig. 1 Fig. 2 Fig. 3

and perpendicular to the neutral axis is the so-called tabular method based upon the formula: $I = \frac{b(h_1^3 - h^3)}{3}$ in which I = the moment of inertia about axis DE, Fig. 1, and b, h and h_1 are dimensions as given in the same illustration.

The method may be illustrated by applying it to the section shown in Fig. 2 and for simplicity of calculation shown "massed" in Fig. 3. The calculation may then be tabulated as shown in the accompanying table. The distance from the axis DE to the neutral axis xx (which will be designated as d) is found by dividing the sum of the geometrical moments by the area. The moment of inertia about the neutral axis is then found in the usual way by subtracting the area multiplied by d^2 from the moment of inertia about the axis DE.

Tabulated Calculation of Moment of Inertia

Section	Breadth b	Height h_1	Area $b(h_1 - h)$	h_1^2	Moment $\frac{b(h_1^2 - h^2)}{2}$	h_1^3	I about axis DE $\frac{b(h_1^3 - h^3)}{3}$
A	1.500	0.125	0.187	0.016	0.012	0.002	0.086
B	0.531	0.625	0.266	0.391	0.100	0.244	0.043
C	0.219	1.500	0.191	2.250	0.203	3.375	0.226
			$A = 0.644$		$M = 0.315$		$I_{DE} = 0.272$

The distance d from DE, the axis through the base of the configuration, to the neutral axis xx is

$$d = \frac{M}{A} = \frac{0.315}{0.644} = 0.49$$

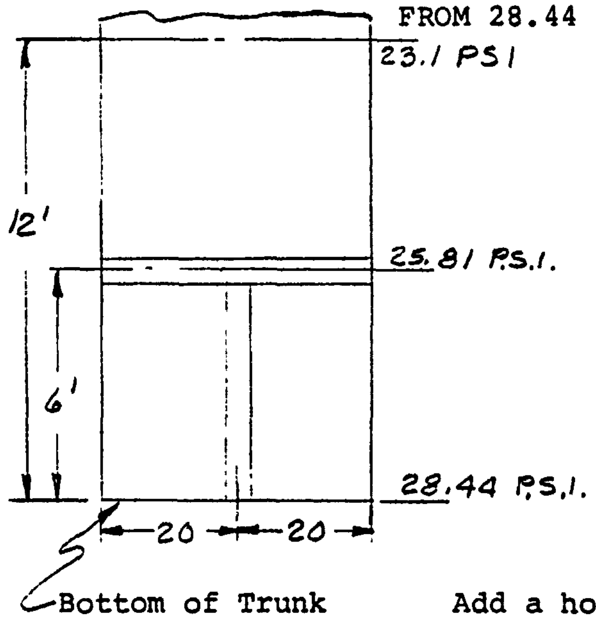
The moment of inertia of the entire section with reference to the neutral axis xx is

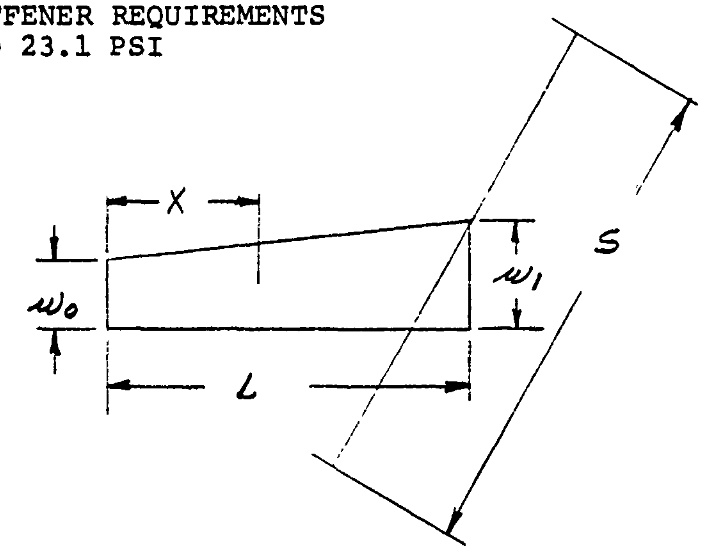
$$I_x = I_{DE} - Ad^2$$
$$= 0.272 - 0.644 \times 0.49^2$$
$$= 0.117$$

Calculations are based on the above formulae's.

SECTION III

SIDE PANEL PLATE & STIFFENER REQUIREMENTS FROM 28.44 TO 23.1 PSI





Bottom of Trunk Side Panel

Add a horizontal & vertical stiffener to bottom 12' of trunk length as shown.

w_o = 25.81 x 20 = 516.2#/In. of Lg.

w_1 = 28.44 x 20 = 56.88#/In. of Lg.

$$X = \frac{72}{52.6}\left(-516.2 + \sqrt{\frac{568.8^2 + (568.8 \times 516.2) + 516.2^2}{3}}\right) = 36.29$$

$$R_o = \frac{72}{6}(2 \times 516.2 + 568.8) = 19214.4 \text{ in. lbs.}$$

$$M = 19214.4 \times 36.29 - \frac{516.2 \times 36.29^2}{2} - \frac{52.6 \times 36.29^3}{432} = 351562.95 \text{ in. lbs.}$$

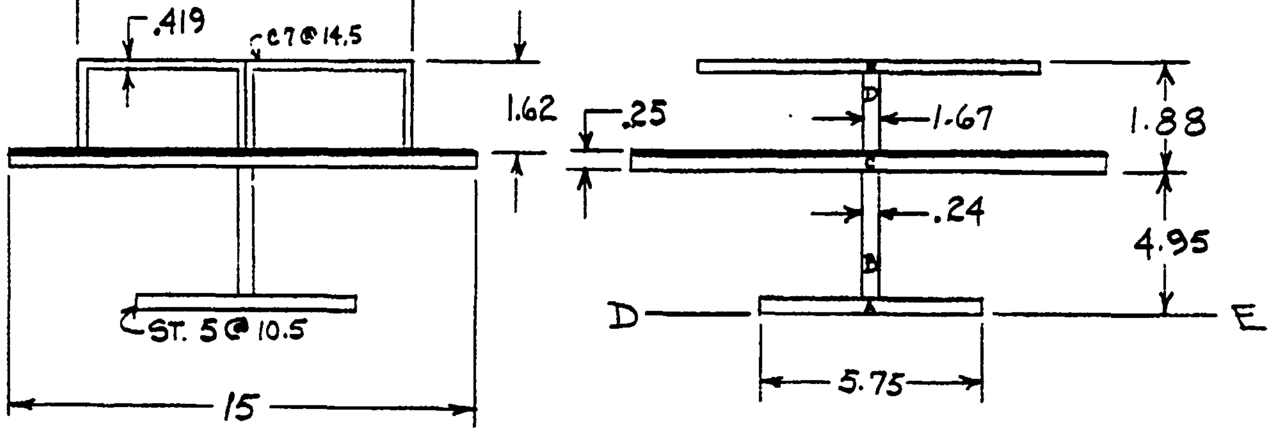
$$Z \text{ Required} = \frac{351562.95}{27000} = \underline{\underline{13.02}} \text{ In.}^3$$

For horizontal stiffener use St. 5 @ 10.5 In.^{3}. See Pg. 7 of conveyor rear panel study.

For vertical stiffener use St. 5 @ 10.5 In.^{3}. See next page for calculations.

TAIL SECTION

REF. DWG 2-1026-99F



Keep thickness of side panel at ¼ thick as indicated. Use 60t for effective width of plating = 15". Reference drawing 2-1026-99F tail frame.

SEC	b	h_1	A	h_1^2	M	h_1^3	IDE
A	5.75	.34	1.95	.12	.34	.04	.076
B	.24	4.95	1.11	24.5	2.92	121.28	9.7
C	15	5.2	3.75	27.04	19.05	140.61	96.65
D	1.67	6.4	2.42	40.96	11.62	262.14	67.65
E	14	6.83	5.86	46.51	38.85	317.22	257.04
			15.09		72.78		431.11

$d = \frac{72.78}{15.09} = 4.82$ $\quad I_n = 431.11 - (15.09 \times 4.82^2) = 80.53 \text{ in.}^4$

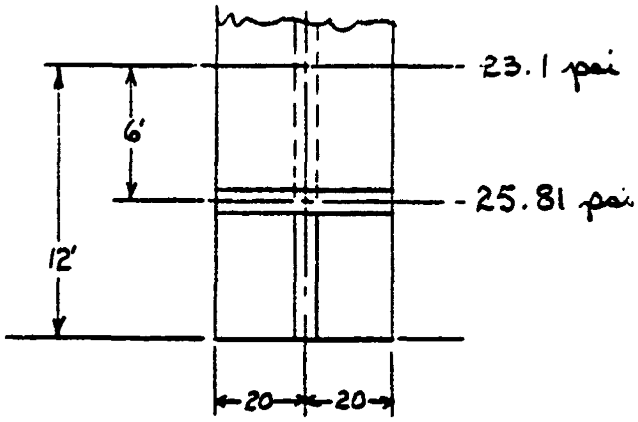
$Z = 16.7 \text{ in.}^3$

$Z \text{ reqd.} = \underline{\underline{13.02}}$

Conclusion

¼ thick plate with horizontal and vertical stiffeners as shown is okay for tail section.

Head Pressure From 25.81 to 23.1 P. S. I.



w_o = 23.1 x 20 = 462 #/in. of length
w1 = 25.81 x 20 = 516.2 #/in. of length

$$X = \frac{72}{53.2}\left(-463 + \sqrt{\frac{516.2^2 + (516.2 \times 462) + 462^2}{3}}\right) = 36.33 \text{ in.}$$

$$R_o = \frac{72}{6}(462 \times 2 + 516.2) = 17282.4 \text{ in. lbs.}$$

$$M = 17282.4 \times 36.33 - \frac{462 \times 36.33^2}{2} - \frac{53.2 \times 36.33^3}{432} = 317074.83$$

$$Z \text{ Required} = \frac{317074.83}{27000} = 11.74 \text{ in.}^3$$

From 23.1 To 20.42 P. S. I.

w_o = 20.42 x 20 = 408.4 w1 = 23.1 x 20 = 462

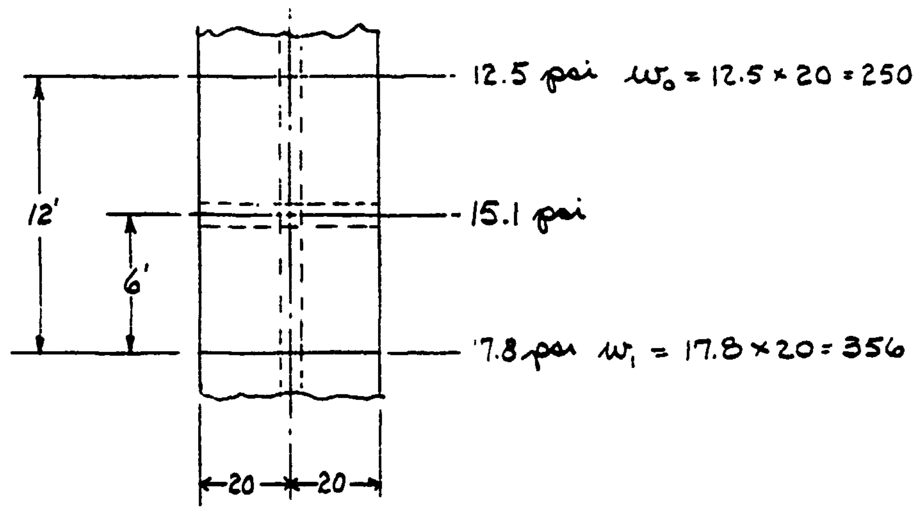
$$X = \frac{72}{53.6}\left(-408.4 + \sqrt{\frac{462^2 + (462 \times 408.8) \times 408.8^2}{3}}\right) = 36.36 \text{ in.}$$

$$R_o = \frac{72}{6}(408.4 \times 2 + 462) = 15345.6 \text{ in. lbs.}$$

$$M = 15345.6 \times 36.36 - \frac{408.8 \times 36.36^2}{2} - \frac{53.6 \times 36.36^3}{432} = 281774.88$$

$$Z \text{ Required} = \frac{281774.88}{27000} = \underline{\underline{10.43}} \text{ in.}$$

Head Pressure From 17.8 to 12.5 P. S. I.



$$X = \frac{144}{106}\left(-250 + \sqrt{\frac{356^2 + (356 \times 250) \times 250^2}{3}}\right) = 74.09 \text{ in.}$$

$$R_o = \frac{144}{6}(2 \times 250 + 356) = 20544$$

$$M = 20544 \times 74.09 - \frac{250 \times 74.09^2}{2} - \frac{106 \times 79.09^3}{864} = 775243.38$$

$$Z \text{ Required} = \frac{775243.38}{27003} = \underline{\underline{28.71 \text{ in.}^3}}$$

standard section is not strong enough. See Pg. 8

By adding a horizontal stiffener to the above, we can change the requirements.

$w_o = 15.1 \times 20 = 302$, $w_1 = 17.8 \times 20 = 356$

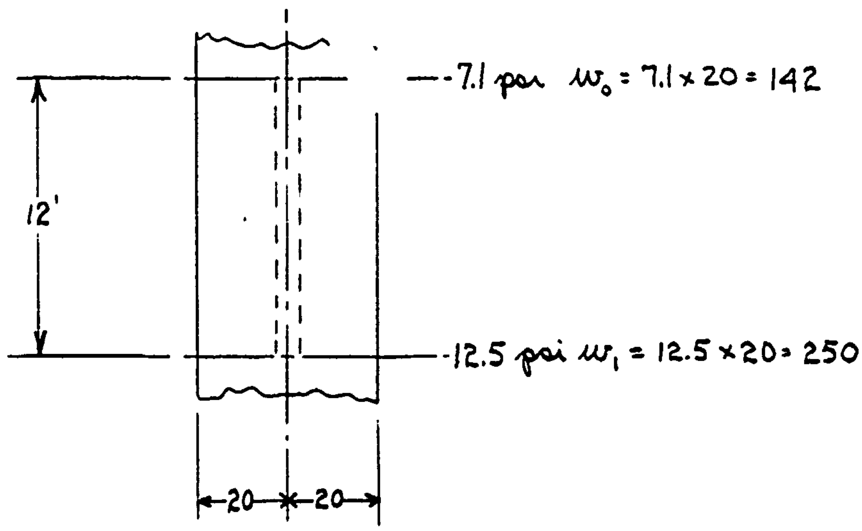
$$X = \frac{72}{54}\left(-302 + \sqrt{\frac{356^2 + (356 \times 302) + 302^2}{3}}\right) = 36.49 \text{ in.}$$

$$R_o = \frac{72}{6}(2 \times 302 + 356) = 11520 \text{ in. lbs.}$$

$$M = 11520 \times 36.49 - \frac{302 \times 36.49^2}{2} - \frac{54 \times 36.49^3}{432} = 213231.88 \text{ in. lbs.}$$

$$Z \text{ Required} = \frac{213231.88}{27000} = \underline{\underline{7.9 \text{ in.}^3}}$$

Head Pressure From 12.5 To 7.1 P. S. I.



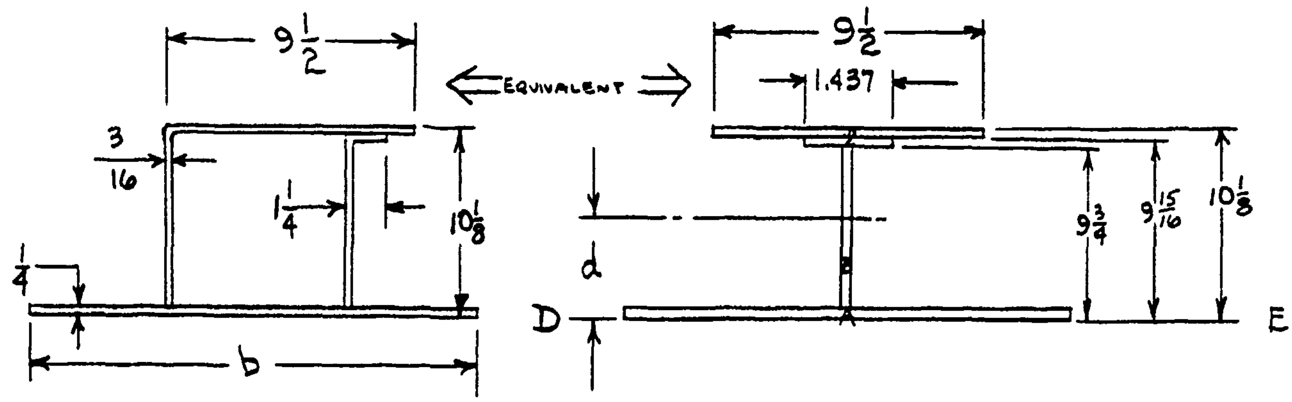
$$X = \frac{144}{108}\left(-142 + \sqrt{\frac{250^2 + (250 \times 142) + 142^2}{3}}\right) = 75.28$$

$$R_O = \frac{144}{6}(2 \times 142 + 350) = 15216$$

$$M = 15216 \times 75.28 - \frac{142 \times 75.28^2}{2} - \frac{108 \times 75.28^3}{864} = 689770.7 \text{ in. lbs.}$$

$$Z \text{ Required} = \frac{689770.7}{27000} = \underline{\underline{25.54 \text{ in.}^3}}$$

Cross Section 2-1026-P3-A-F



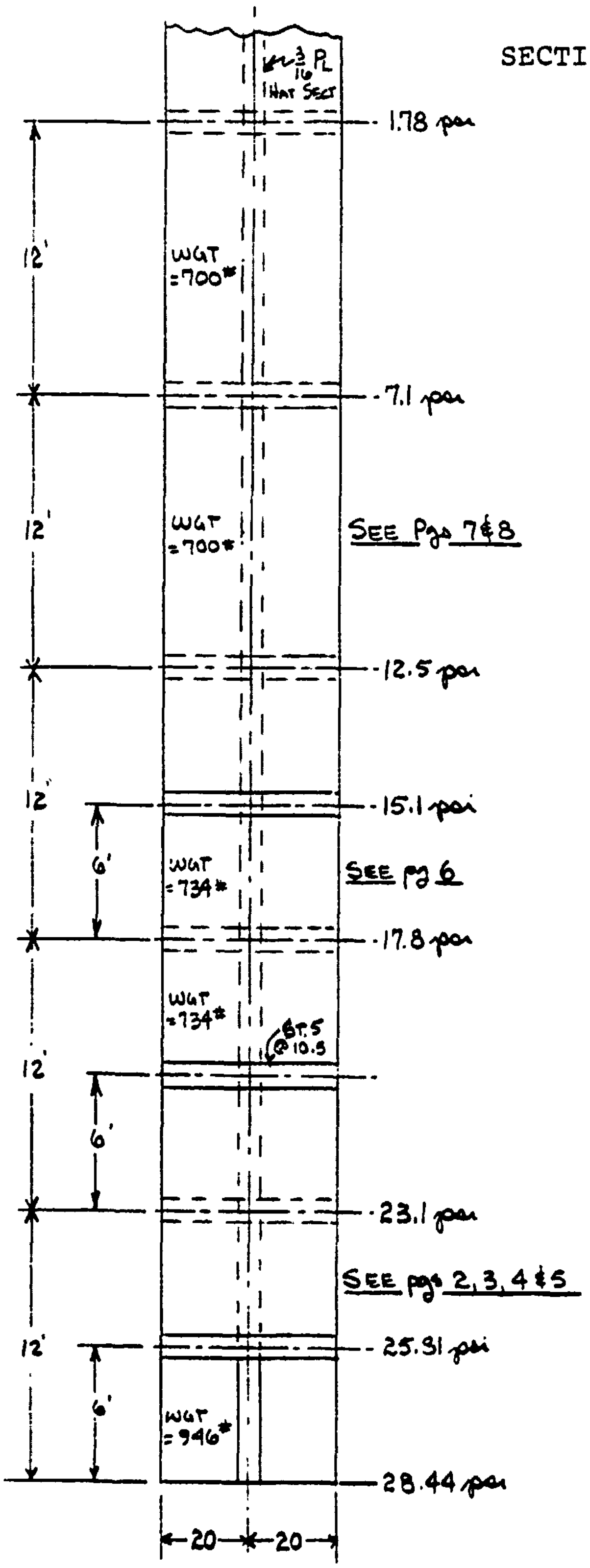
SEC.	b	h_1	A	h_1	M	h_1^3	IDE
A	15	.25	3.75	.062	.46	.015	.075
B	.375	9.75	3.56	95.06	17.81	926.86	115.85
C	1.437	9.93	.269	98.6	2.54	979.15	25.04
D	9.5	10.12	1.78	102.4	18.05	1036.44	181.42
			9.359		38.86		322.385

$d = \frac{38.86}{9.359} = 4.15$ In. $= 322.385 - 9.351 \times 4.15^2 = 161.19$

Minimum $Z = \frac{161.19}{5.97} = \underline{\underline{27 \text{ in.}^3}}$

Conclusion

The standard side panel with a 1/4 thick plate and a 3/16 thick hat section without outside stiffeners is good down to 28 ft. head or 12.5 P. S. I. The required Z = 25.54 in.^{3} from Pg. 6
The available Z = 27 in.^{3}



Typ. trunk side panel showing arrangement of vertical and horizontal stiffeners with 1/4 thick plate.

The standard side panel with a 1/4 thick plate and 3/16 thick plate hat section can be used down to 12.5 P. S. I. without any outside stiffeners below 12.5 P. S. I. Horizontal stiffeners will be added at 6 ft. intervals as indicated. At the bottom section (1) vertical stiffener will also be added. All outside stiffeners will be St. 5 @ 10.5.

The maximum length of a panel will be 12' long. A horizontal stiffener should be at each 12' span unless a deck is at this height.

Total weight = 5564# per side

This is comparable with 6885 lbs. per Section I, Pg. 7

Conclusion

A standard side panel with a 1/4 thick plate and a 3/16 thick hat section can be used the full length of the trunk with a minimum amount of change to make it W. T. by doing the following:

1. Add horizontal and vertical stiffeners to the bottom panel since the hat section cannot extend into the tail frame.

2. Add horizontal stiffeners at 6' intervals as indicated on Pg. 9.

3. All calculations have not taken the horizontal channels located on the inside of the side panels into consideration although they do add strength to the construction of the trunk.

The main advantage to this study is that the basic trunk will remain the same whether the trunk is W. T. or Non T.

The addition of a minimum amount of stiffeners will be required to change from a Non T. trunk to a W. T. trunk.

DESIGN STUDY

OF

CONVEYOR OVERLOAD PROTECTION

REVISION I

CONTRACT N00024-72-C-5500

CDRL ITEM B001AK

Submittal Date:

Submitted By: KORNYLAK CORPORATION

400 Heaton Street

Hamilton, Ohio 45011

CONVEYOR OVERLOAD PROTECTION REVISION I

INTRODUCTION

REF: (a) NAVSEC LETTER 6164D2/SJO SER. 685

(b) KORNYLAK LETTER 2-1026/D. SMITH DATED 29 June '76

(c) CONVEYOR SPEC. SHIPS C-5552

1. In compliance with paragraph 2 of ref. (a), this study shall cover the following:

   (a) Review of mechanical friction clutches with torque limiting capabilities.

   (b) Also an evaluation of positive type torque limiting devices.

   (c) An electrical overload device to monitor the power circuit as part of the conveyor overload protection.

2. Based on the parameters formed by ref. (a) and (c), along with the reasons for disapproval of the posidyne unit submitted with ref. (b), the different types of torque limiting devices has been narrowed down to a select few which have such features as simplicity, minimal maintenance, economical and no external power requirements for transmitting and/or limiting torque.

3. Although friction type clutches are the most common type of torque limiting device, a realtively new positive type device which uses a spring loaded ball or key detent for limiting torque transmittal will also be reviewed and considered in this study.

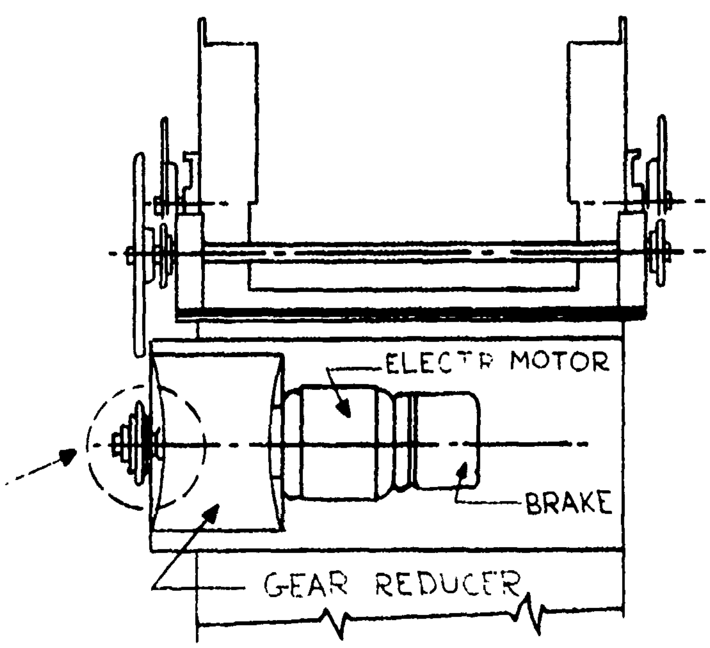
4. Since the tray overload protection device as defined in paragraph 3.4 (b) and 3.4.22 (d) of ref. (c) has been temporarily shelved in Phase II, another type of electrical overload device must be selected to provide added protection to the conveyor system.

TABLE OF CONTENTS

1. TORQUE LIMITER LOCATION

1.1 Most torque limiting devices are recommended, by the manufacturer, to be located on the output shaft or slow speed side of the reducer (ref. Fig. 1) for the following reasons:

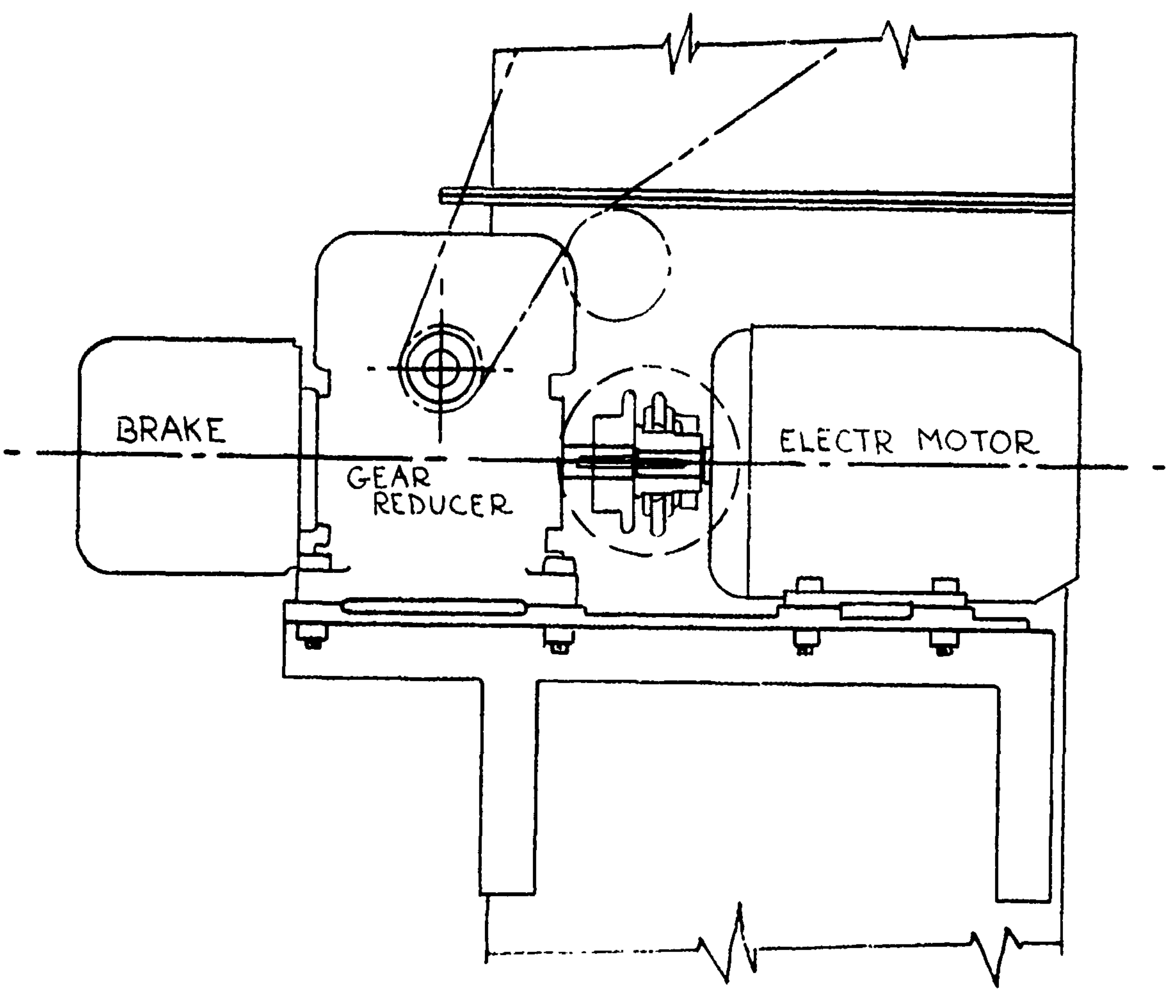
(a)	Helps prevent friction disc glazing.	This can occur during continuous or prolonged slippage at high speed.
(b)	Dampens motor startup torque.	This will allow a closer torque setting to be made to full load requirements.
(c)	Reducer error in torque setting.	An error in torque setting on the input side of the reducer is magnified by the reducer ratio at the output shaft.



Torque Limiter located on Output Shaft of Reducer

1.2 The torque limiter location as shown in Fig. 1 is not ideal for application in a drive train for a vertical type conveyor because the location is on the load side of the reducer and also in between the brake and the load. Eventual wear or even accidental lubrication from excessive lubricant on a drive chain could cause slippage under load, allowing the conveyor to backtravel and cause damage.

1.3 Therefore, the proper location for the torque limiter in this case and as specified by SPEC. SHIPS-C-5552, is in between the motor and the input shaft of the reducer (ref. Fig. 2) thus defeating the advantages mentioned in paragraph 1.



Torque Limiter located on Input Shaft of Reducer

MAIN CONVEYOR DRIVE FIG. 2

2. DESIGN REQUIREMENTS AND LIMITATIONS

2.1 Requirements by specification

Ships C-5552 Ref. paragraph 3.5.13 & 3.5.15

(a) Friction clutch to include a flexible coupling.

(b) Adjustable setting to allow slippage between 110-115% of rated full load.

(c) Further adjustment required to allow dynamic testing per paragraph 4.3.2.

2.2 TORQUE LIMITER SIZE SELECTION

2.2.1 Drive calculations per K.C. Drawing 2-1026-DC Rev. A indicate that drive sizes from 3 HP to 10 HP inclusive are required to cover the required 20 ft. to 90 ft. center distance range of conveyors.

2.2.2 Past purchases of standard 85# Capacity Vertical Stores Conveyors for Navy ships, ranging from the shortest units on the "LSD" Class ships to the tallest units on the "AS" and "CVA" Class ships, provide the following input collected from 255 installations.

13%, (a quantity of 34) would have a 3 HP drive

72%, (a quantity of 184) would have a 5 HP drive

13%, (a quantity of 35) would have a 7½ HP drive

2%, (a quantity of 5) would have a 10 HP drive

The above figures are based on the 85# size conveyor center distances applied to the drive selection chart on the above drawing, using the 60" tray space column.

2.2.3 The torque range and bore sizes required for each drive size are as follows,

Drive H.P.	3	5	7½	10
Operating Lb. Ft.	9	15	22.5	30
Torque Lb. In.	(108)	(180)	(270)	(360)
(1) Input Motor Bore	1.625	1.625	1.875	1.875
(2) Output Reducer Bore	1.625	1.750	1.875	2.000
Adj. Range 50% to 150% of Oper. Torque Lb. In.	54 / 162	90 / 270	135 / 405	180 / 540

(1) Motor input bore based on 3 speed constant torque motors using 254T through 286T Frames.

(2) Reducer bore sizes based on using Cone Drive HU Models with 4", 6", 7" and 8" C.D.

2.3 Other design requirements:

(a) Automatic shut-off limit switch activated by Torque Limiter at point of overload.

(b) Bi-directional operation.

(c) All position (vertical or horizontal) mounting

(d) Externally and infinately adjustable.

(e) Capable of withstanding frequent overload.

(f) Steel construction (no cast iron permitted).

(g) Automatic reset in either direction.

(h) Maintain accuracy of trip setting under abnormal conditions. Such as corrosive salt laden atmosphere, ambient temperature range of -20° to $+120^{\circ}$ F, high humidity, dusty or oily atmosphere.

(j) Limited maximum setting and/or tamperproof setting.

(k) Enclosed unit (for environmental protection).

(l) Minimum maintenance.

3. MECHANICAL FRICTION TYPE CLUTCHES

3.1 The most common torque limiting devices available are mechanical friction type clutches which basically consist of two different designs, Rim or Drum and axial type.

3.2 The rim or drum type (ref. Fig. 3) are of the internal-expanding or external-contracting shoe type. Both types rely on a combination of air pressure and release springs or centrifugal force for control. The expanding type is commonly used for continuous slippage in controlled torque applications while the contracting type is best suited for cyclic applications, neither of which are suitable for vertical conveyor operation or overload protection.

3.3 The axial type consist of the following designs, cone, disc and multidisc.

3.3.1 CONE DESIGN - Ref. Fig. 4 and 4A

The present tendency is to limit cone type clutches to low speeds where sudden pick-up of load is not objectionable. Past performance of certain cone type clutches, operating at motor speed (1750/1800 RPM), failed to provide protection since the cone design is susceptible to heat build up during high speed slippage. This causes a malfunction or breakdown of the friction cone which defeats its torque limiting capabilities, and for this reason will not be considered any further.

3.3.2 DISC DESIGN - Ref. Fig. 5 and 5A

This design is the simplest and most economical, mechanical friction type clutch available, and is mechanically held in constant engagement by one or more springs.

3.3.3 Both makes shown in Fig. 5 and 5A, offer the following features in that,

(a) They can slip during engagement thus allowing the drive to pick-up and accelerate the load with minimum shock.

(b) They can be used at either high or low speed engagements and will slip under shock loads, providing cushioning to the system.

(c) They automatically re-engage when the overload is removed.

3.3.4 Disadvantages of this design are as follows:

(a) Inaccuracy of torque setting and repeatability due to changes in humidity, temperature, friction lining wear or contamination by oil, rust or dirt.

(b) Erratic or unstable spring pressure based on torque setting being in low range of spring pressure.

(c) No definate movement available (other than normal slippage) to use for tripping a motor cutout limit switch.

3.4 MULTI DISC TYPE - Ref. Fig. 6 thru 6H

3.4.1 Multi Disc units are similar in operating principle to single disc units. The major difference being that alternately stacking or interleaving of the driven and driving discs can increase the friction area thus creating a greater torque capacity for a given clutch diameter.

3.4.2 Limitations to this design are,

(a) Restrictions to the number of starts per hour when compared to a single disc clutch of the same mechanical capacity and material, due to heat build up when they are used in air as a dry clutch without lubrication.

(b) Loss of capacity at the time of engagement due to disc sliding resistance.

(c) Complexity of parts and more maintenance is required when compared to a single disc unit.

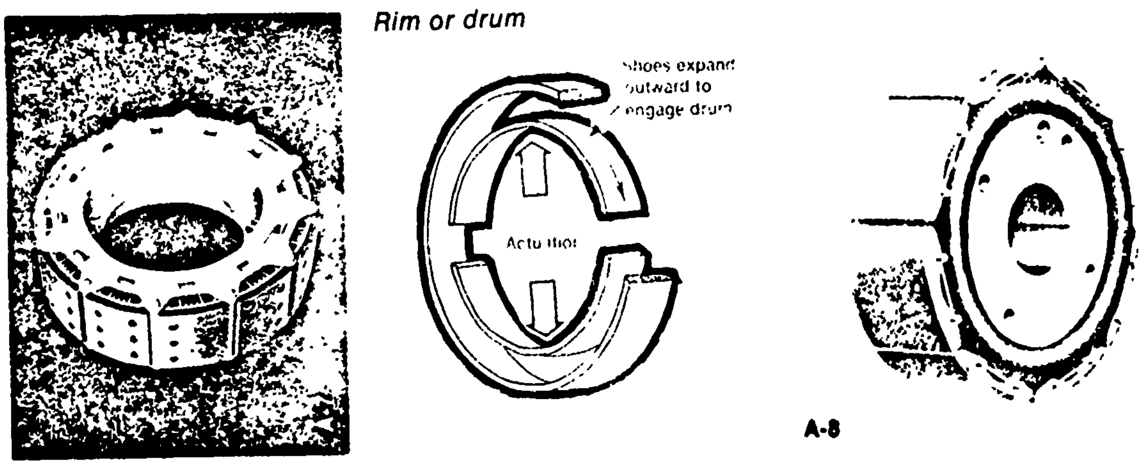
(d) Periodic cleaning of the discs is required to assure that the adjustment or setting remains the same, even for a wet type clutch.

(e) Accumulation of occasional slippage will eventually cause a false overload tripping of the unit shown in Fig. 6.

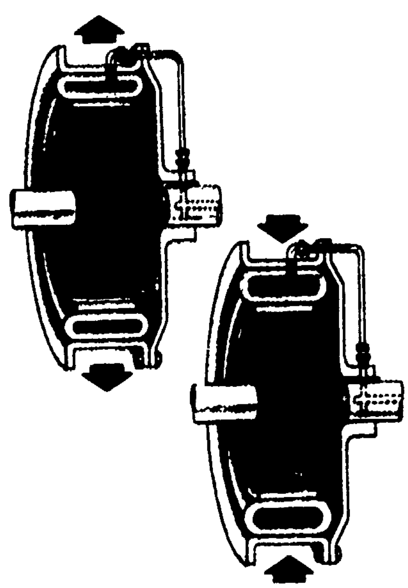
3.4.3 The unit shown in Fig. 6 is not recommended for use where the overload is only slightly higher than the maximum overload. The overload recommended by the manufacturer must be either a heavy shock or a suddenly applied load substantially greater than the maximum working load. Therefore, a gradual build up of overload might not trip the unit.

3.4.4 The overall picture presented by this unit indicates that many variables are involved in determining the overload limits or setting for this type of clutch and that maintenance is required at regular intervals for either the wet or dry type, to maintain the correct setting when found. Therefore, it is our opinion that the multi disc type is too complex and has several undesirable features which are not suitable for this application.

RIM OR DRUM TYPE CLUTCHES

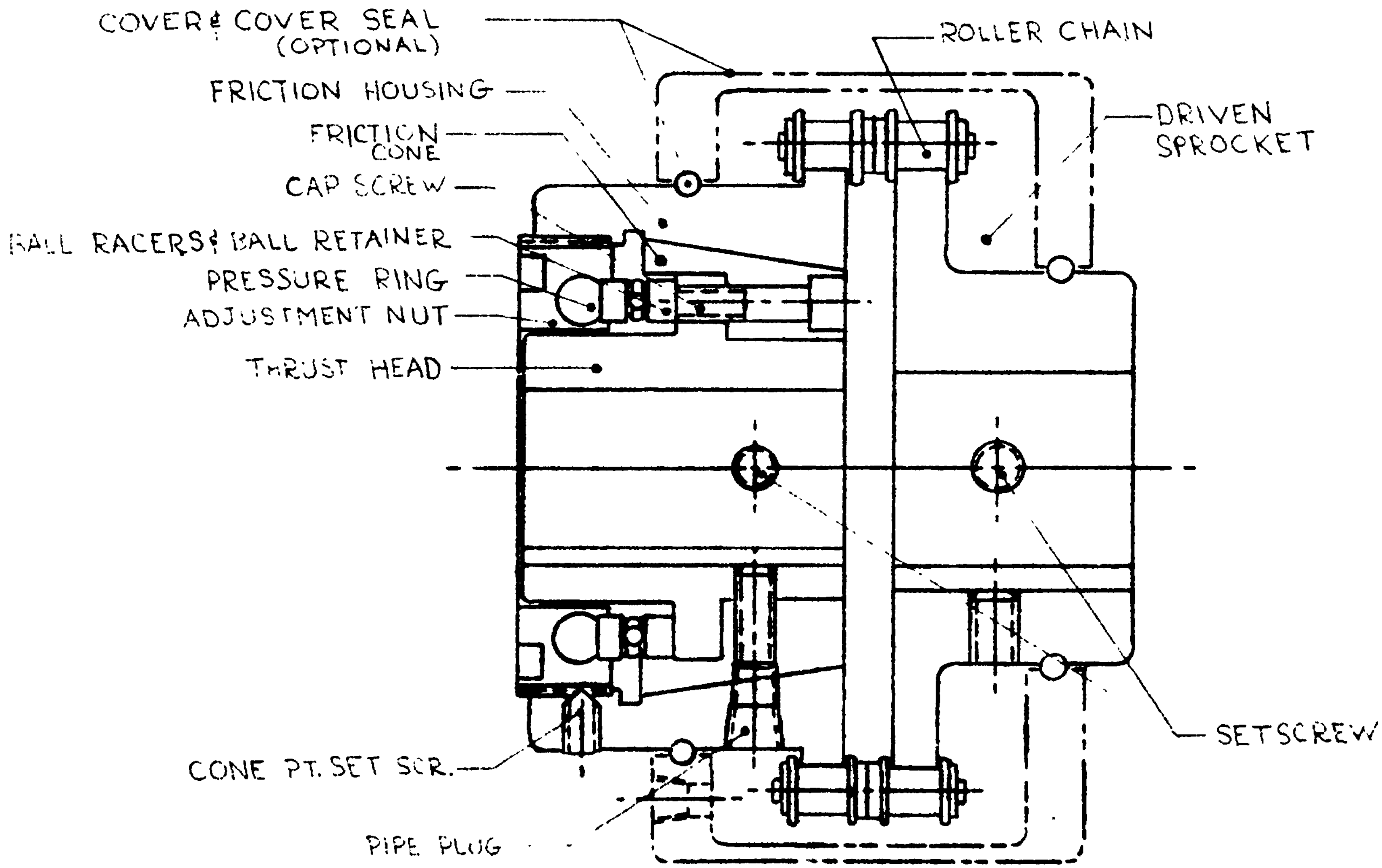


INTERNAL - EXPANDING TYPE

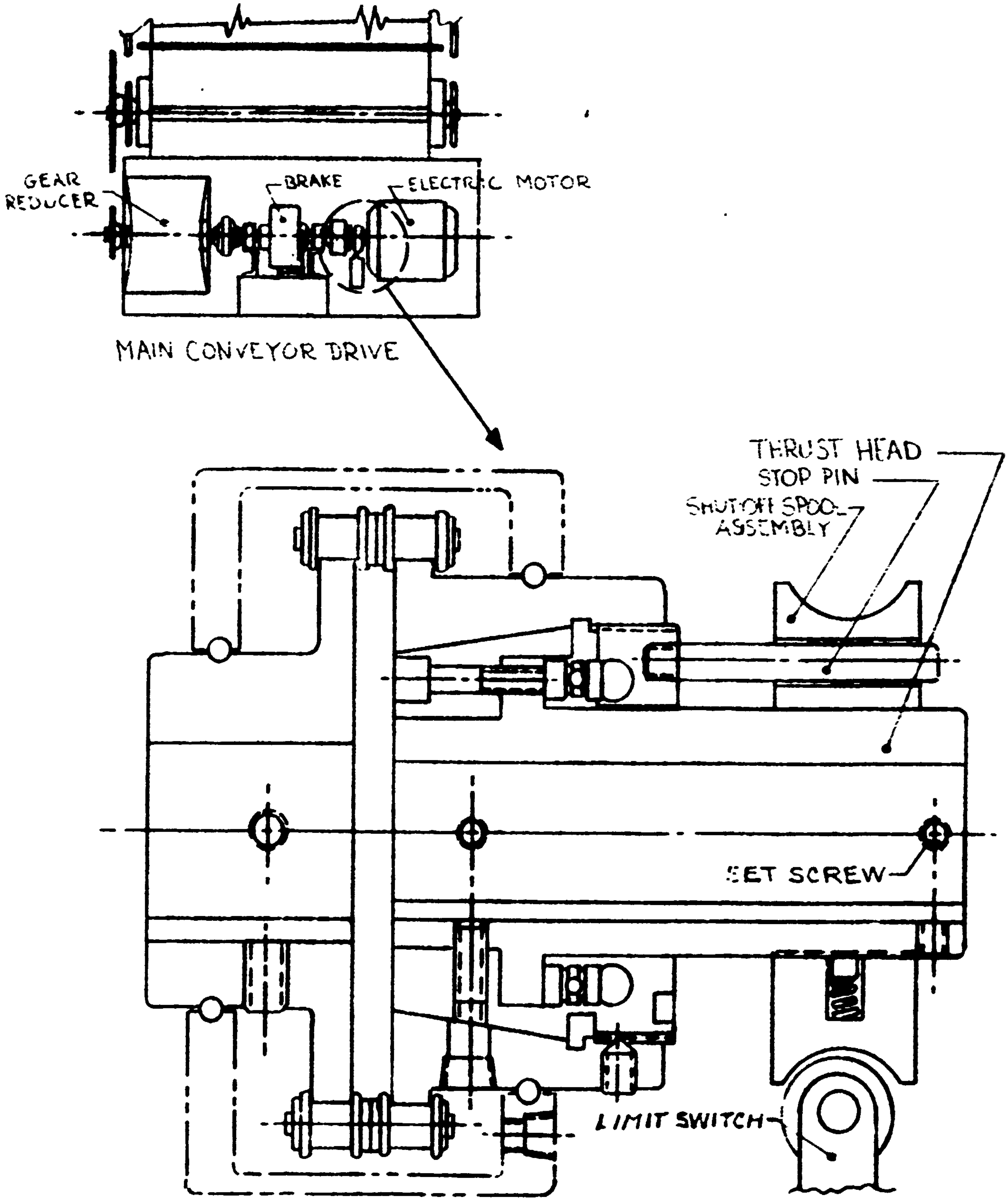


EXTERNAL - CONTRACTING TYPE

FIG. 3



TORQUE LIMITER

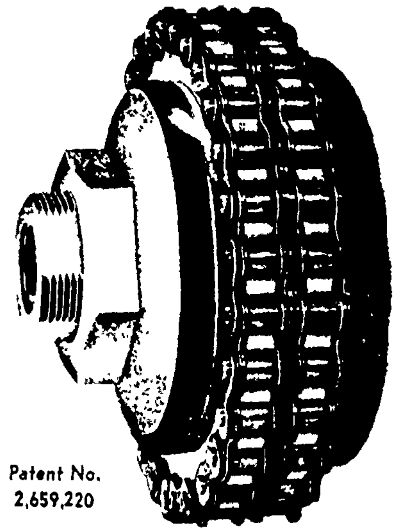

GEAR REDUCER
BRAKE
ELECTRIC MOTOR
MAIN CONVEYOR DRIVE
THRUST HEAD
STOP PIN
SHUTOFF SPOOL ASSEMBLY
SET SCREW
LIMIT SWITCH

DALTON MODEL "OSDC"

OVERLOAD SAFETY DEVICE

The Dalton OSDC (Overload Safety Device Coupling) provides overload protection through the use of an OSD unit combined with a roller chain coupling half counterbored to fit the OSD flange. Standard double-width roller chain is used to couple the basic OSD unit and the coupling half.

The OSDC can be set with a torque wrench for maximum load desired. The unit functions as a roller chain coupling until an overload occurs, causing the OSDC to dis-engage. The device is automatically re-engaged when the overload is eliminated.



Patent No. 2,659,220

Coupling No.	Weight Lbs.	Max. Ft. Lbs. Torque	No. of Springs	MAXIMUM BORE Coupling Half	MAXIMUM BORE OSD Half	MINIMUM BORE Coupling Half	MINIMUM BORE OSD Half	Coupling Half No.	OSD Sprocket No.	Coupling Chain No.
OSDC-225	4	35	1	1½"	¾" *	⅜"	⅜"	4020A	40A20GC	D40
OSDC-225D	4	50	2	1½"	¾" *	⅜"	⅜"	4020A	40A20GC	D40
OSDC-337	9½	100	1	2¼"	1" *	½"	½"	4027A	40A27GC	D40
OSDC-337D	9½	175	2	2¼"	1" *	½"	½"	4027A	40A27GC	D40
OSDC-450	16	190	1	3"	1⅜"	¾"	¾"	5026A	50A26GC	D50
OSDC-450D	16	285	2	3"	1⅜"	¾"	¾"	5026A	50A26GC	D50
OSDC-600	30	320	1	4"	1⅝"	1"	1"	6031A	60A31GC	D60
OSDC-600D	30	440	2	4"	1⅝"	1"	1"	6031A	60A31GC	D60
OSDC-750	46	550	1	5"	2½"	1"	1"	8027A	80A27GC	D80
OSDC-750D	46	775	2	5"	2½"	1"	1"	8027A	80A27GC	D80

*For maximum bore on OSD225, OSD225D, OSD337 and OSD337D, a shallow keyway is used of ½ standard depth. Use the next larger size "OSD" unit when a standard keyway is desired.

In furnishing a coupling half to be used in the "OSDC", care must be taken that a standard cut tooth sprocket is not used. The teeth of the "OSDC" coupling half are cut with special tooth form to compensate for shaft misalignment.

FORMULA FOR TORQUE-HORSEPOWER (Foot Pounds)

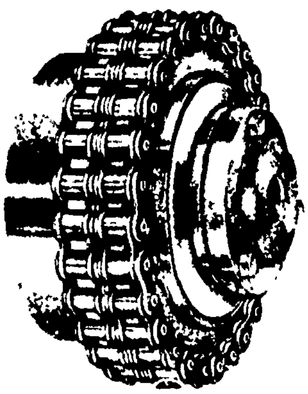
$$\text{TORQUE (Ft. Lbs.)} = \frac{\text{HP} \times 5252}{\text{RPM}}$$

$$\text{HORSEPOWER} = \frac{\text{Torque} \times \text{RPM}}{5252}$$

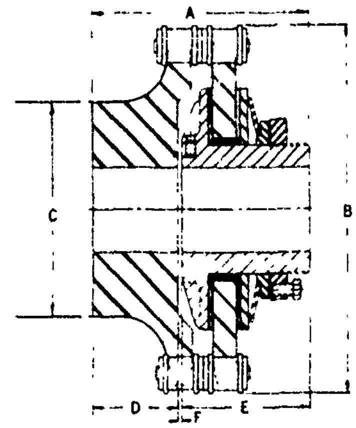
MORSE

Torque Limiter couplings

torque limiter coupling



The Torque Limiter Coupling* combines overload slip protection with the ability to couple driving and driven shafts. It is an assembly consisting of a standard Morse Torque Limiter and a roller chain coupling. A stock "A" plate sprocket with ground faces serves as the center member of the Torque Limiter, and it is coupled to a type "B" sprocket by an ASA double strand roller chain which is easily connected by a single pin. This construction provides a dependable and easy-to-assemble flexible coupling having shaft misalignment compensation.



Model Number	Misalign Max. Parallel	Misalign Max. Angular	Torque Capacity Lbs. Ft. Min.	Torque Capacity Lbs. Ft. Max.	Max. Bore Torque Limiter	Max. Bore Cplg. Spkt.	Stock Min. Plain Bore† Torque Limiter	Stock Min. Plain Bore† Cplg. Spkt	List Price Min. Plain Bore*	Stock Finished Bore Torque Limiter	Stock Finished Bore Cplg. Spkt.	List Price Finished Bore*	Spkt. Size	Dimensions (Inches) A	B	C	D	E	F	Approx. Wt. Lbs.
250A-1C	010	½°	5	20	⅞	1¼	½	½	$ 92 60	½ ⅝ ¾ ⅞	—	$ 96 60	4.	3	4	2	1	1⅞	⅛	4½
250A-2C	.010	½°	10	40	⅞	1¼	½	½	97 70	½ ⅝ ¾ ⅞	--	101.70	422	3	4	2	1	1⅞	⅛	4½
350A-1C	.012	½°	15	55	1	1[illegible]	[illegible]	[illegible]	124 20	¾ ⅞ 1	--	129.30	524	4[illegible]	5[illegible]	2[illegible]	1½	2⁷⁄₁₆	⅛	11½
350A-2C	.012	½°	25	110	1	1[illegible]	[illegible]	[illegible]	135 90	¾ ⅞ 1	—	140 10	524	4[illegible]	5[illegible]	2[illegible]	1½	2⁷⁄₁₆	⅛	11½
500A-1C	015	½	35	155	1⅝	2[illegible]	[illegible]	[illegible]	235 00	⅞, 1, 1³⁄₁₆, 1⅛, 1¼, 1⅜, 1½, 1⅝	--	241 30	628	4[illegible]	7[illegible]	4	1⅝	3	⅛	27
500A 2C	015	½°	65	310	1⅝	2[illegible]	[illegible]	[illegible]	248 30	⅞, 1, 1³⁄₁₆, 1⅛, 1¼, 1⅜, 1½, 1⅝	—	254 60	628	4[illegible]	7[illegible]	4	1⅝	3	⅛	27
700A 1C	020	½°	85	420	2½	3[illegible]	1	1	420 70	1½, 1¾, 1¹⁵⁄₁₆, 2	--	427 90	828	6[illegible]	9[illegible]	6	2⅝	3⅞	⅛	69
700A-2C	020	½°	165	800	2½	3[illegible]	1	1	444 20	1½, 1¾, 1¹⁵⁄₁₆, 2	--	452 00	828	6[illegible]	9[illegible]	6	2⅝	3⅞	⅛	69

*Coupling Sprocket Minimum Plain Bore
†Torque Limiter only, includes one (1) setscrew

reworking charges for each half non-standard bore keyway or setscrew

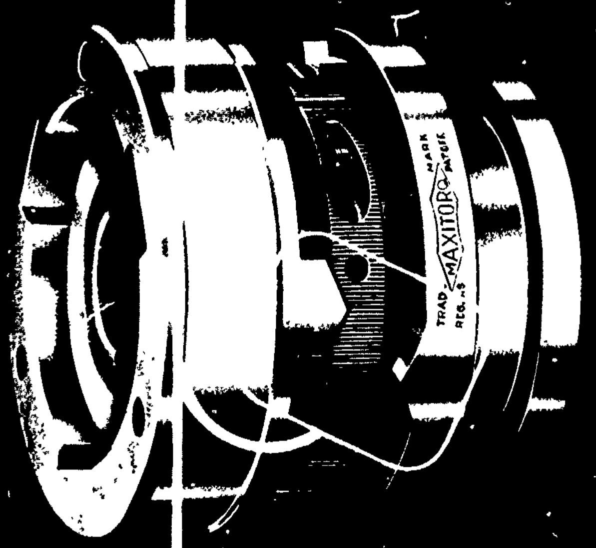
Model No.	Torque Limiter Rebore Mach. Charge	Rebore Set-Up Charge	Keyway Mach. Charge	Keyway Set-Up Charge	Add'l Setscrew Mach. Charge	Add'l Setscrew Set-Up Charge	Coupling Sprocket Rebore, Keyway, and Setscrew (No reduction for omitting any of these features) Mach. Charge	Set-Up Charge
	QUANTITY 1-49							
250A-1C 250A-2C	$7.50	$59.70	$.85	$59 70	$1 35	$59 70	$ 8 70	$121 75
350A-1C 350A-2C	9.50	59.70	1 00	59.70	2.00	59 70	11 70	121 75
500A-1C 500A-2C	10.50	59.70	1.85	59.70	2 35	59 70	13 35	121.75
700A-1C 700A-2C	19 70	59.70	3 00	59.70	3 35	59 70	24.00	121.75

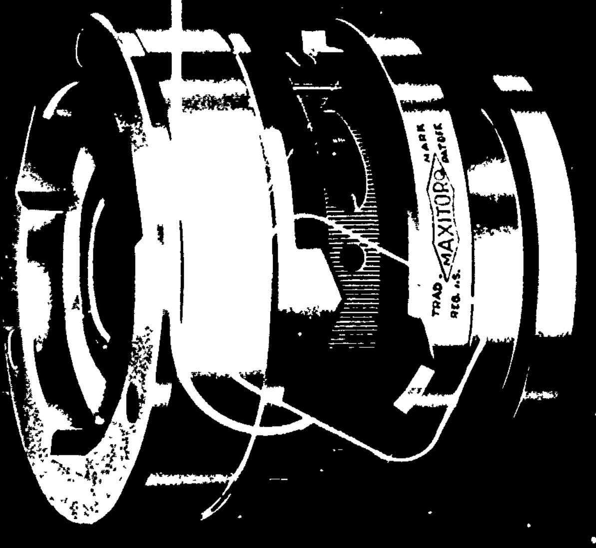
Torque Limiter & Coupling Sprocket Standard Bore Tolerances	
½ to ¹⁵⁄₁₆	+.0015 —.000
1 to 1¹⁵⁄₁₆	+.002 —.000
2 And Over	+.003 —.000

Reworking Charge (Net), ea = Machining Charge + (Set Up Charge / Quantity Identical Units)

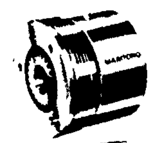
Maxitorq

AUTOMATIC OVERLOAD RELEASE CLUTCHES

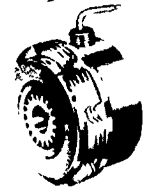




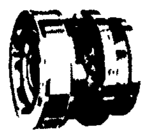
MAXITORQ PRODUCTS



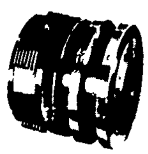
SERIES AH AIR OR HYDRAULIC CLUTCHES OR BRAKES
BULLETIN NO. 101



SERIES 9000A ELECTRIC CLUTCHES AND FAIL-SAFE CLUTCHES OR BRAKES
BULLETIN NO. 90A & 95



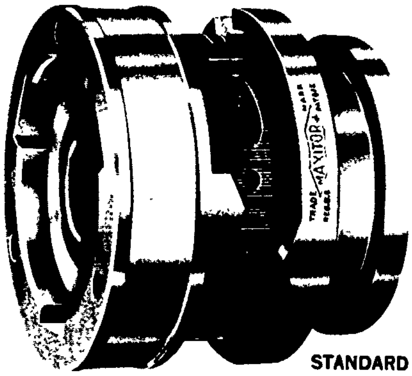
AUTOMATIC OVERLOAD RELEASE CLUTCHES
BULLETIN NO. 150A



STANDARD SINGLE AND DOUBLE CLUTCHES OR BRAKES
BULLETIN NO. 50

DISC-PAC "HEART" OF MAXITORQ CLUTCHES
BULLETIN NO. 55

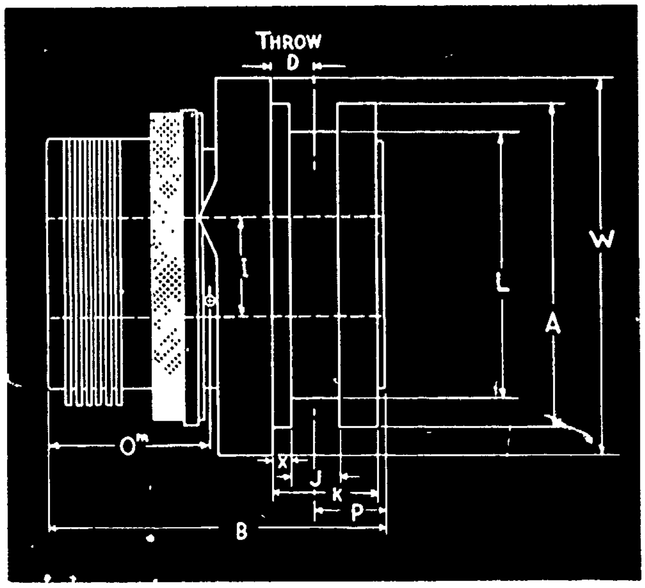
ALSO AVAILABLE CLUTCH DISCS, SEPARATOR SPRINGS, DRIVING CUPS



STANDARD CAMS

Maxitorq

Floating Disc, Automatic



SIMPLE, EFFICIENT, "BUILT-IN PROTECTION" FOR POWER DRIVEN EQUIPMENT

The Maxitorq Overload Release Clutch has been designed for applications where it is desired to protect a machine and its products against damage resulting from accidental overloading of the mechanism. This type of clutch promises freedom from costly shutdowns, resulting in substantial savings to the user.

When overload occurs, the clutch automatically releases, stopping the machine and preventing damage. When the jammed condition has been cleared, the clutch is reengaged and the machine is again in operation.

The overload release clutch is specifically recommended for applications where the nature of the overload will be either a heavy shock or a suddenly applied load of a magnitude substantially greater than the normal driving load. Jamming and clogging of the mechanism, imposing as it does a severe shock on the driving components, is characteristic of this type of overload. The clutch will perform most effectively under these conditions. Protection from such an overload, in the past, has usually been accomplished by the use of shear pins. The overload release clutch is not recommended for applications where the overload will be but slightly greater than the normal driving torque.

By means of a simple finger-tip adjustment, the clutch can be set to transmit the normal running load for a particular application. It automatically disengages when an overload occurs, and positively slips into neutral.

DOUBLE CLUTCHES. The overload release feature can be incorporated on double clutches on special order on either one or both ends.

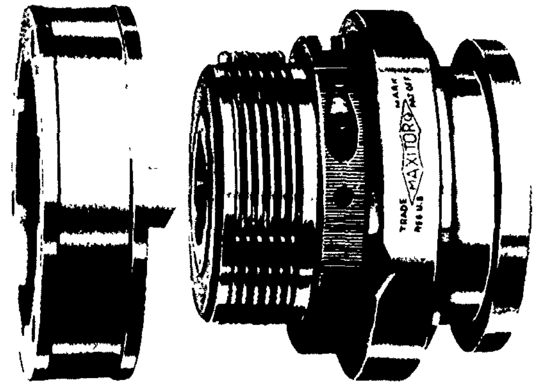
NOTE: Maxitorq Clutches as furnished can run dry or in oil. We specifically recommend Series A oils. If high gear loading or worm and wheels are adjacent to the clutch and indicate extreme pressure additives that would reduce clutch torque, please contact the factory for recommendations.

SPECIFICATIONS . . . CLUTCHES NOTE: Dardelet self locking full dog point set screw must bottom in spotted hole in shaft.

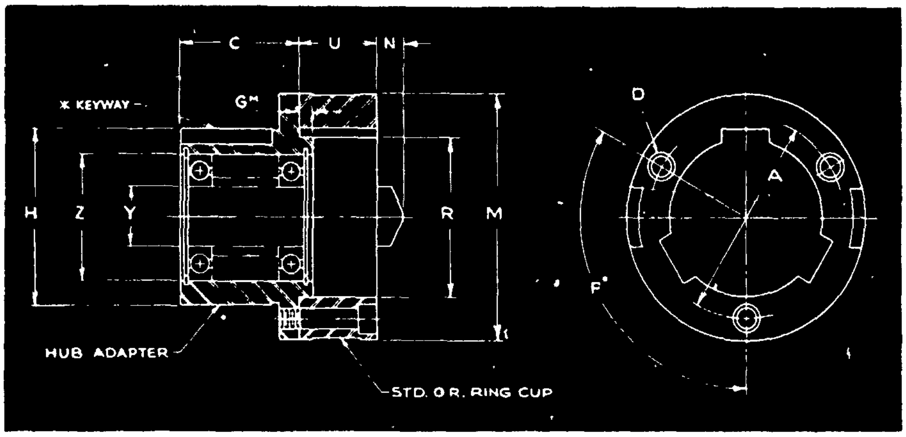
Clutch No.	HP @ 100 RPM	Dynamic Torque Ft. Lbs.	Static Slip Point Torque (Approx.) Ft. Lbs.	Axial Sleeve Pressure Lbs	Std. Body Bores I +.001 .000			A	B	Throw D	J	K	L	P	W	X	O*
					Min.	Max	Keyway Max.										
20	1 10	7	14	15	1/2	5/8	3/16 Pin	2 19/32	2 3/8	3/8	375	3/4	2 1/8	9/16	3 1/8	1/16	1 5/16
21	1/4	13	26	20	3/4	7/8	3/16 x 3/32	2 19/32	3	3/8	.500	15/16	2 1/8	5/8	3 1/8	1/8	1 41/64
22	1/2	27	54	30	1	1 1/8	3/16 x 3/32	3 3/16	3 15/32	7/16	500	1 1/16	2 5/8	45/64	3 5/8	11/64	1 15/16
23	1	53	106	30	1 1/4	1 3/8	1/4 x 1/8	3 15/16	4 1/32	17/32	625	1 15/64	3 1/4	51/64	4 5/8	3/16	2 17/64
24	1 3/4	92	184	40	1 1/2	1 5/8	5/16 x 5/32	4 1/4	4 1/32	17/32	625	1 15/64	3 9/16	51/64	5	3/16	2 17/64
25	3	158	316	60	1 3/4	1 7/8	3/8 x 3/16	4 15/16	4 13/16	39/64	.750	1 7/16	4 1/16	61/64	5 7/8	13/64	2 23/32
26	5	263	526	80	2	2 1/4	7/16 x 7/32	5 15/32	5	39/64	750	1 7/16	4 5/8	61/64	6 5/8	13/64	2 29/32
27	10	525	1,050	105	2 1/2	2 3/4	9/16 x 9/32	7 19/32	6 11/32	7/8	812	1 3/4	6 1/2	1 1/8	9 1/8	5/16	3 3/4
28	15	788	1,576	150	2 3/4	3	9/16 x 9/32	8 5/8	6 9/16	7/8	812	1 3/4	7 1/2	1 1/8	10 1/8	5/16	3 11/32

*Dardelet set screw.

• OVERLOAD RELEASE CLUTCHES



INVERTED CAM TYPE for single registration enabling registering two shafts to a specific relationship.



*Keyway to suit conditions. Bearings-Spacer-Retaining Rings, Adapter furnished by customer.

DRIVING RING CUPS FOR OVERLOAD RELEASE CLUTCHES

Overload release-type driving ring cups are the means by which the overload release clutch is connected to either the driven or driving member.

Ring cups are accurately machined and finished ground. All working surfaces are heat-treated. The hub or cut-off coupling type adapter is furnished by user to suit installation requirements.

Because of the unusual cam construction, it is recommended that we furnish overload release-type driving ring cups as well as the clutch. We are equipped to make them correctly in reasonable quantities. Through an associated company we can provide a package incorporating the Carlyle Johnson clutch unit and other components required for a complete installation. If this latter course is desired, preliminary drawings, a complete quotation, assembly instructions and recommendations will be provided.

SHIFTERS

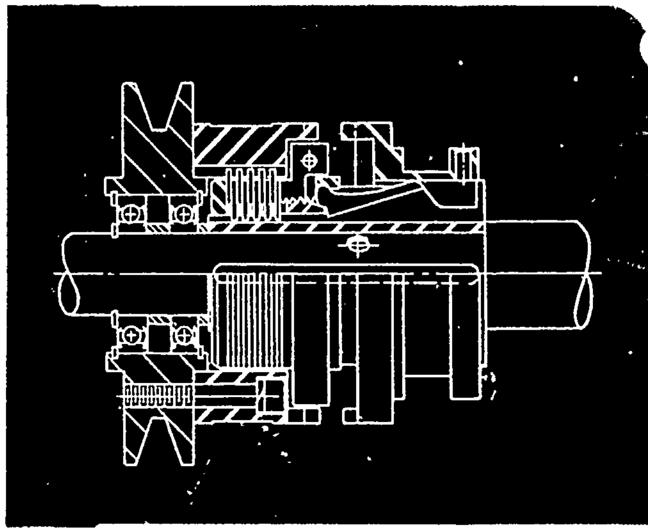
Special overload release shifters are available for clutch sizes 20 through 26. Shoes and studs are available for all sizes including 27 and 28 for riveting into shifter yokes designed by the customer. The user can, if desired, incorporate a limit switch in the power input line. This switch is operated in conjunction with the clutch shifter sleeve to open the circuit when clutch release is effected by the overload. Maxitorq Overload Release Clutches may be used on a continuous shaft, or as a cut-off coupling type for connecting two shafts.

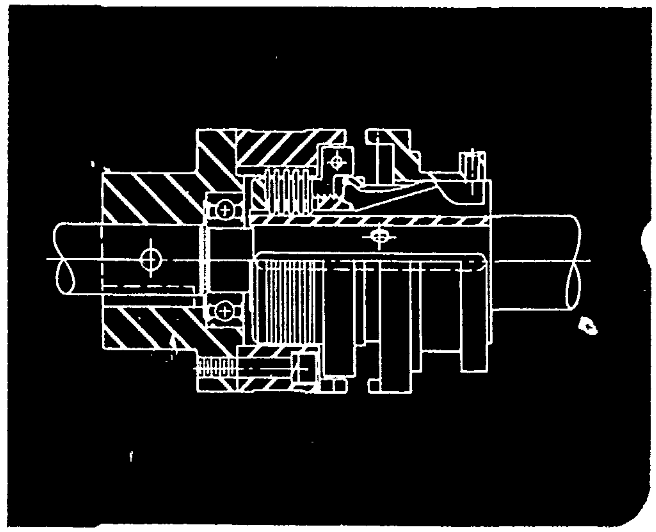
OVERLOAD RELEASE CLUTCH DRIVING RING CUPS AND ADAPTERS

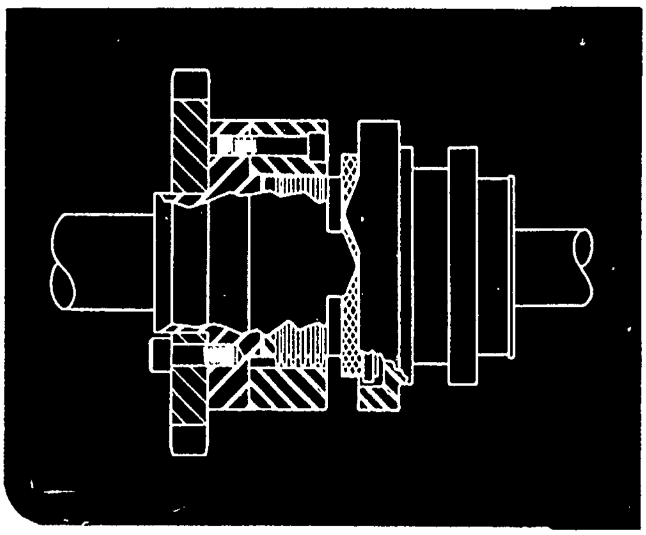
Clutch No.	C	H	Shaft Bore Y		Z	M	R I. D.	U	Gᴹ	Cap Screw Size	D Drilled Holes	No. of Thru Holes	A*	F°	N
20	TO SUIT CONDITIONS	TO SUIT CONDITIONS	1/2	5/8	TO SUIT BEARING O.D.	3.125 3.123	2.017 2.015	11/16	3/16	1/4	17/64	3	2 9/16	120°	11/32
21			3/4	7/8		3.125 3.123	2.017 2.015	1 1/32	3/16	1/4	17/64	3	2 9/16	120°	11/32
22			1	1 1/8		3.625 3.623	2.517 2.515	1 5/32	3/16	1/4	17/64	3	3 1/16	120°	11/32
23			1 1/4	1 3/8		4.625 4.623	3.267 3.265	1 5/16	5/32	5/16	11/32	3	3 15/16	120°	15/32
24			1 1/2	1 5/8		5.125 5.123	3.767 3.765	1 5/16	5/32	5/16	11/32	3	4 7/16	120°	15/32
25			1 3/4	1 7/8		6.125 6.123	4.517 4.515	1 19/32	3/16	3/8	13/32	4	5 5/16	90°	37/64
26			2	2 1/4		7.125 7.120	5 517 5.515	1 25/32	3/16	3/8	13/32	6	6 1/4	60°	19/32
27			2 1/2	2 3/4		9.125 9.120	7.017 7.015	2 3/16	3/16	1/2	17/32	6	8 1/16	60°	13/16
28			2 3/4	3		10.125 10.120	8.017 8.015	2 7/16	1/4	1/2	17/32	6	9 1/16	60°	13/16

*Bolt circle

Maxitorq Clutches may be used for a wide variety of applications. Combinations of several types are often used to control speeds, feeds and reversing mechanisms in one machine tool.







Ask for Recommendations

There are so many varied applications of this overload release clutch that we suggest you submit your clutch problem to our engineering department for practical recommendations.

Let's talk
MAXITORQ

THE CARLYLE JOHNSON MACHINE CO.
52 MAIN STREET · MANCHESTER, CONN 06040

MAINTENANCE AND ADJUSTMENT OF MAXITORQ CLUTCHES

The Carlyle Johnson Machine Company guarantees Maxitorq Clutches against imperfections in materials and workmanship. To assure good service the clutch must be kept properly adjusted and maintained. We offer the following bulletin as a guide to better clutch performance.

STANDARD CLUTCH ADJUSTMENT

The clutches are factory adjusted, yet, the machine builder may make a further adjustment to suit his particular requirements. During the run-in period of any machine it may be necessary to take up the adjustment due to initial wear-in period. To make a change in adjustment, lift the lock spring and move the adjusting ring one notch at a time. These notches can be seen on the outside diameter of lever retaining ring inside of the adjusting ring. Be sure to replace spring after making adjustment. To adjust the split type ring loosen the cap screw and rotate not more than 10 degrees at a time, making sure to tighten the cap screw after each adjustment. Contact the machine builder if the desired results are not obtained. CAUTION: Be careful not to over adjust the clutch. This condition does not allow the discs to separate sufficiently in the neutral position, causing loss of freeness, excessive wear, and possible breakage of the separator springs.

OVERLOAD RELEASE ADJUSTMENT

First back off the adjusting ring until the clutch will immediately throw out when power is applied. Then slowly take up one notch at a time. If the split type ring is used, do not turn the ring more than 10 degrees at a time. Apply the power after each change until the clutch will just stay in engagement. To over adjust means that too much overload must occure before the clutch will disengage itself. If the user wishes to protect for light loads, then a careful adjustment must be made. Under this condition, it is possible to adjust sufficiently to carry the load, but minor variations of torque will cause the clutch to slip by small amounts until the cams interfere and disengage a few times a day. It is up to the user to decide the degree of protection most suited to his particular application. Care must be taken to keep all disc surfaces clean to assure that the adjustment will remain the same. NOTE:—If a variable speed drive is used, the adjustment must be changed if the speed is to be changed.

WET CLUTCH: (All steel discs)

This clutch should always be run in oil. Periodic checks should be made to make sure oil is clean and free from carbonization. Depending upon the usage, gear boxes should be drained, flushed out and new oil put in on a scheduled basis. NOTE:— Special low speed applications that have been approved by the factory to run without oil should be maintained like a dry clutch.

DRY CLUTCH: (Alternate steel and bronze faced discs)

This type of clutch has been designed so that the <u>disc</u> unit may be run as a dry unit without lubrication. It may also be run in oil. It has been the experience of the factory that carbonization will form if oil heavier than 200 viscosity is used. Heavy oil also reduces the freeness of the neutral position due to the hydraulic shear value of the oil and at the same time increases the working temperature as well as reducing the torque value of the unit. A clutch that is running dry and usually unprotected from all forms of contamination must be cleaned at regular intervals to assure proper operation. Unless the clutch unit is badly corroded, it is generally unnecessary to take the unit apart. Take an oil can filled with any of the commercial solvents and work the solvents down through the disc assembly and into the lever and cam system. The discs are readily accessible if a milled type cup is used. If our ring type cup is used, it is necessary to work the solvent in through the milled slots under the shifter sleeve. This milled slot runs the full length of the body and will carry the solvent into the disc assembly. On a single clutch, it may be necessary to use the finger to dam up the back of the milled slot on the shifter sleeve end of the body so the solvent will run into the discs instead of out the back end. When you have worked a sufficient amount of solvent into the clutch, start up the machine and engage and disengage the clutch to free up the unit. Repeat this procedure until the clutch works correctly. If this method fails, then it will be necessary to remove the clutch from the machine——disassemble and clean thoroughly. Before reassembling the clutch, study the exploded view and the following description to be sure the parts are put back in the right sequence.

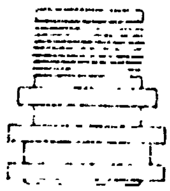


FIG. 1

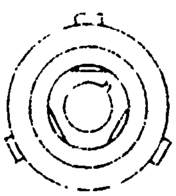


FIG. 2

HOW TO DISASSEMBLE THE CLUTCH

Place the clutch as shown in figure (1). Looking down on the clutch as in figure (2), raise lock spring, rotate adjusting ring in a clockwise direction until the face of adjusting ring just begins to draw away from the adjacent inner disc. Press down on the end locking plate until it can be rotated 60 degrees. This will free the bayonet lock and allow the end locking plate to be removed, followed by the discs, separator springs, thrust collar, adjusting ring, and levers. Unless the shifter sleeve or wedges are damaged or worn, it is not necessary to remove the lever retaining ring which is pressed on the body. Make sure that the lever retaining ring is pressed squarely up against the shoulder onto which it is pressed. Thoroughly clean all parts and reassemble, replacing any worn or damaged parts.

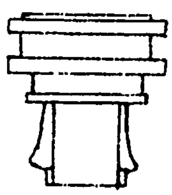


FIG. 3

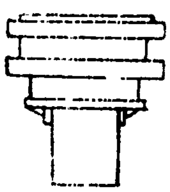


FIG. 4

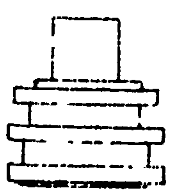


FIG. 5

HOW TO REASSEMBLE CLUTCH

Place the thrust collar on the small diameter of the body with the three milled slots facing toward big diameter end. Rotate the thrust collar so the milled slots line up with the milled slots in the body. Place as shown in figure (3) assembling a lever in each milled slot in the body. Then with the fingers—raise thrust collar and levers up until the round head of the levers is in the circular recess in the lever retaining ring, as in figure (4). Now turn the unit over and screw on the adjusting ring as in figure (5) until the face of the adjusting ring is flush with the face of the thrust collar. Putting a light pressure on the face of the adjusting ring with the thumbs, engage the shifter sleeve with the fingers to be sure that the lever system is working correctly. Put on the first disc, making sure you have chosen a disc with the lugs on the inside diameter. Next add a separator spring, then a disc with the lugs on the outside diameter. Continue to assemble the discs in this manner, if steel and bronze discs are used, until ten discs have been assembled for the #21, #22; twelve discs for the #23, #24, #25; fourteen discs for the #26; sixteen for the #27, and eighteen for the #28 clutch. When all steel discs are used, twelve are required for the #21 and #22; fourteen for the #23, #24 and #25; and sixteen for the #26.

continued next page

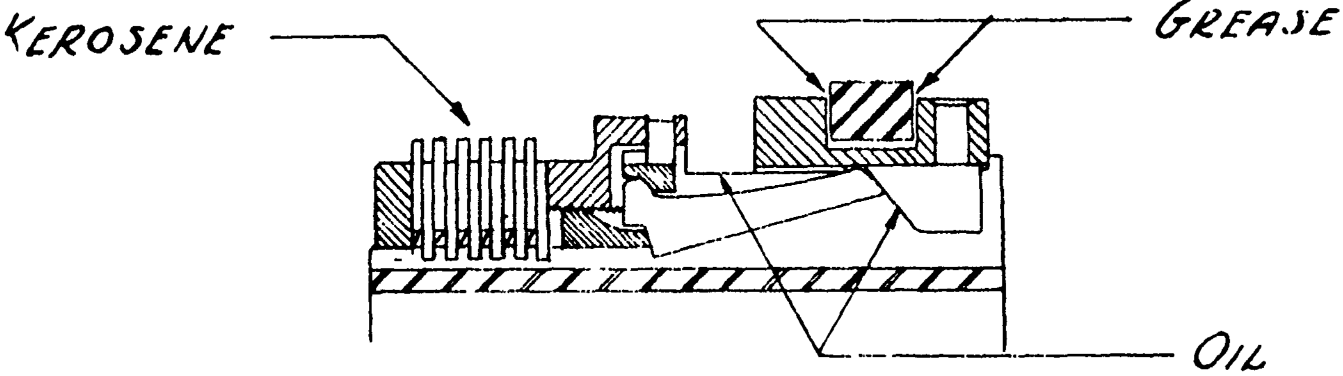
Next assemble the end locking plate by matching up the milled faces on the end of the clutch body. Press lock plate against discs and rotate it. Release the hand pressure and rotate until the plate snaps into locked position. Take up on the adjusting ring until there is a distinct snap when the clutch engages. This is considered to be a normal clutch adjustment.

SUGGESTED MAINTENANCE PROGRAM FOR DRY CLUTCHES

Field experience has shown that a schedule of periodic flushing with kerosene keeps the clutch discs in good condition. At the same time, kerosene carries a light lubricant which is absorbed by the porous structure of the powdered bronze facing.

The shifter sleeve should be lubricated where it slides on the body as well as the lever ends that come in contact with the wedges in the sleeve. A light oil, perferably No. 10 or 20 motor oil, is suggested at these points.

The shifter shoes in the shifter sleeve groove wear better if "Lubriplate" or an equivalent grease is used sparingly. See diagram below---

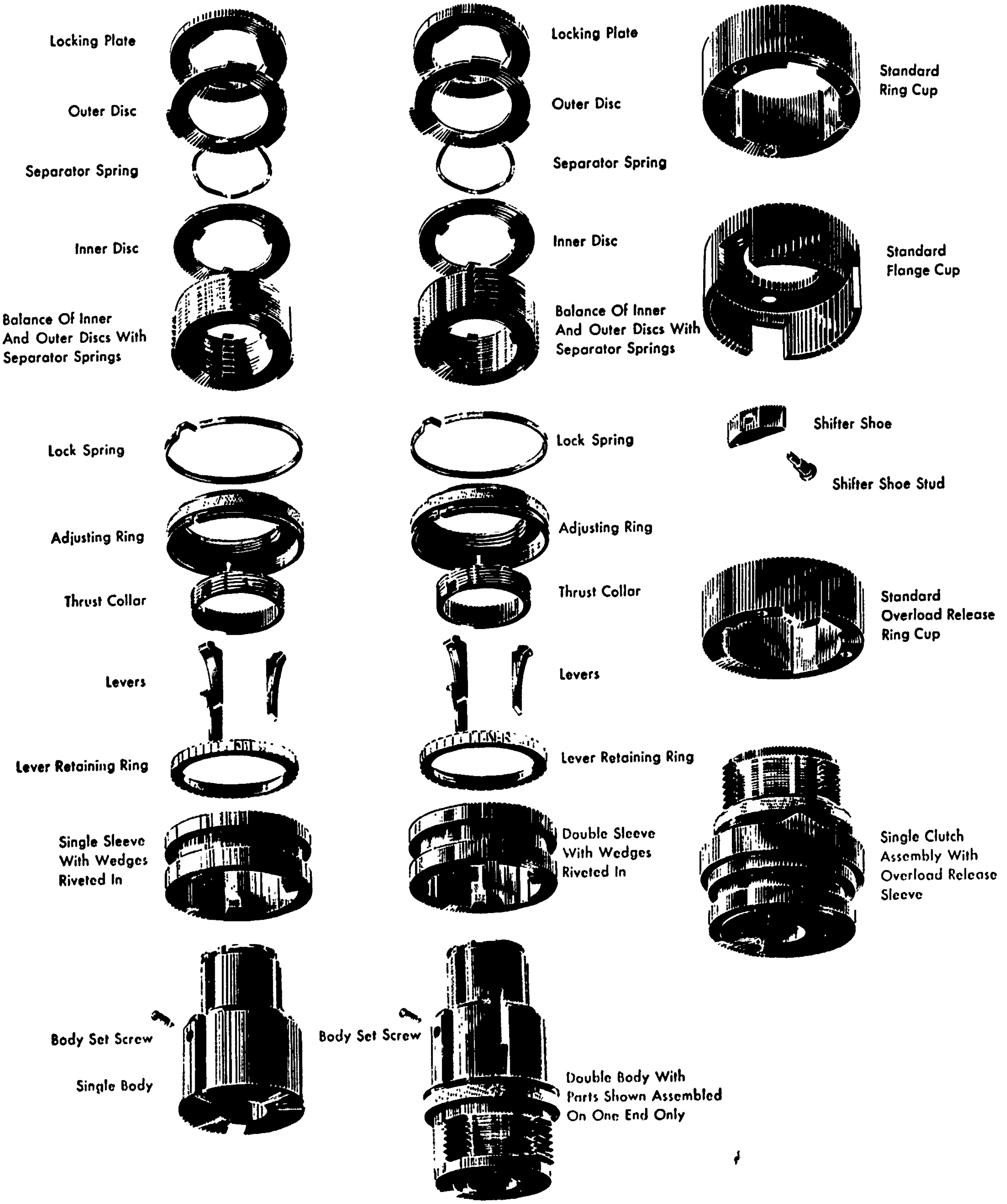


Experience will establish how often this program should be repeated to give best results.

BULLETIN No. 52

REPAIR PARTS LIST

FOR MAXITORQ MECHANICAL CLUTCHES



FOR ORDERING — SEE OTHER SIDE

READ THIS before ordering parts

Each part listed is identified by a part code number which serves as a reference to enable our Parts Department to interpret your requirements. Because the list covers more than one size clutch, it is of utmost importance that you specify not only the part code number and name of the part required, but, also the CLUTCH SIZE AND SERIAL NUMBER (stamped on O.D. of Sleeve), and whether for SINGLE, DOUBLE or OVERLOAD RELEASE TYPE CLUTCH.

Some Maxitorq clutches contain parts which have been modified to a machine builder's specification, such as special clutch bodies and driving cups which can only be identified with serial number.

The above information will help us to better serve you and will, thereby, avoid delays and expense occasioned by idle equipment when our Parts Department is obliged to wire or write for serial number or other information.

STANDARD SINGLE CLUTCH

Part Code No.	
103	Single Body (specify bore and keyway)
104	Single Sleeve (complete with wedges)
105	Adjusting Ring
107	Wedges
108	Thrust Collar
109	Lock Spring (specify width)
110	Levers
111	Lever Retaining Ring
112	Outer Steel Disc (specify quantity)
112-2	Outer Bronze Faced Disc (specify quantity)
113	Inner Steel Disc (specify quantity)
113-1	Inner Bronze Faced Disc (specify quantity)
114	Separator Springs (specify quantity)
115	Locking Plate
116	Body Set Screw

STANDARD DOUBLE CLUTCH

Part Code No.	
101	Double Body (specify bore and keyway)
102	Double Sleeve (complete with wedges)
	All other parts same as for Single Clutch

STANDARD OVERLOAD-RELEASE CLUTCH

Part Code No.	
104-1	Single Sleeve, Overload Release type
	All other parts same as for Single Clutch

STANDARD CLUTCH ACCESSORIES

Part Code No.	
106-4	Standard Ring Cup
106-6	Standard Overload Release Ring Cup
	Standard Flange Cup
117	Shifter Shoes
118	Shifter Shoe Studs

HOW TO ORDER

Specify part code number, description, clutch size, and serial number. For example:

1 PART NO. 103, SINGLE BODY, 1¼" BORE,
¼" x ⅛" KEYWAY, NO. 23 SIZE CLUTCH,
SERIAL NO. 101562.

THE CARLYLE JOHNSON MACHINE COMPANY

MANCHESTER, CONNECTICUT, 06040

See Reverse Side

5M-5-76 TBS

Printed in U.S.A.

4. POSITIVE TYPE TORQUE LIMITERS

4.1 After reviewing all the different types of mechanical friction type clutches as requested and not finding a design which offers better features than have been previously used on existing vertical conveyors, it is apparent that other types of torque limiting devices should be considered at this point.

4.2 Spring loaded ball or key detent, positive type torque limiters which disengage, rather than slip, at a predetermined setting, are becoming more available and competitive in the commercial field of power transmission and offer a variety of new and different features which will be presented and evaluated in the following portion of this study.

4.3 The different makes and designs which are presently on or about to be placed on the market, that will be reviewed at this time are, Autogard, Rite-Torq, Form-Gard and Helland Torq-Tender.

4.4 With the torque limiter location established between the motor and reducer, an allowance for starting torque must be made for a positive type unit since there is no slippage. The selected torque range should have a minimum adjustment of 50% above and below the calculated operating torque required. The overload tripping torque setting should be at least 40% greater than the operating torque to prevent the torque limiter from tripping on start up.

4.5 To provide closer overload protection of 110-115% of rated full load, an electrical overload device to monitor the power circuit is required to supplement a positive type torque limiter.

4.6 AUTOGARD TORQUE LIMITER

4.6.1 The torque limiter recommended by Autogard for vertical conveyor operation with a motor cutoff switch is shown in Figure (7), drawing #AAC-206N/ACT/2/03.

4.6.2 The #2 size unit selected for this application, incorporates a torsionally soft coupling with a single position reset overload release, having a torque range of 20 to 1451 lb. in. (1.67 to 121 lb. ft.). Three different coil springs are required to cover the above torque range for 3 thru 10 HP drives.

4.6.3 The elastomer elements of the coupling half are made of "Perbunam", a synthetic material which is oil and chemical resistant and will operate satisfactorily in a salt laden atmosphere with an ambient temperature range of -25° to $+175^{\circ}$ F. The coupling will allow a maximum shaft misalignment of 0° -24' angular and .032" parallel.

4.6.4 The "ACT" type overload unit uses (3) ½" diameter balls, each located on a different radius so that two (2) revolutions of movement are required to reset the unit after disengagement, thus cutting down on the wear rate when compared with the "AC" type unit, where the (3) balls are located on the same radius.

4.6.5 The torque limiter is bidirectional and will reset automatically. At the point of disengagement from an overload, the cutoff switch shuts off the motor and allows the brake to set on the reducer or load side of the drive. During the short period of time that the brake brings the conveyor movement to rest, (normally 4 to 6 revolutions of the reducer input shaft). The motor will continue to rotate and shift the detent balls thru the reset position until the motor inertia drops below the overload trip setting which will allow the unit to reset.

4.6.6 Other features are:

(a) Limited torque adjustment above maximum specified setting by using calibrated spacers beneath the spring.

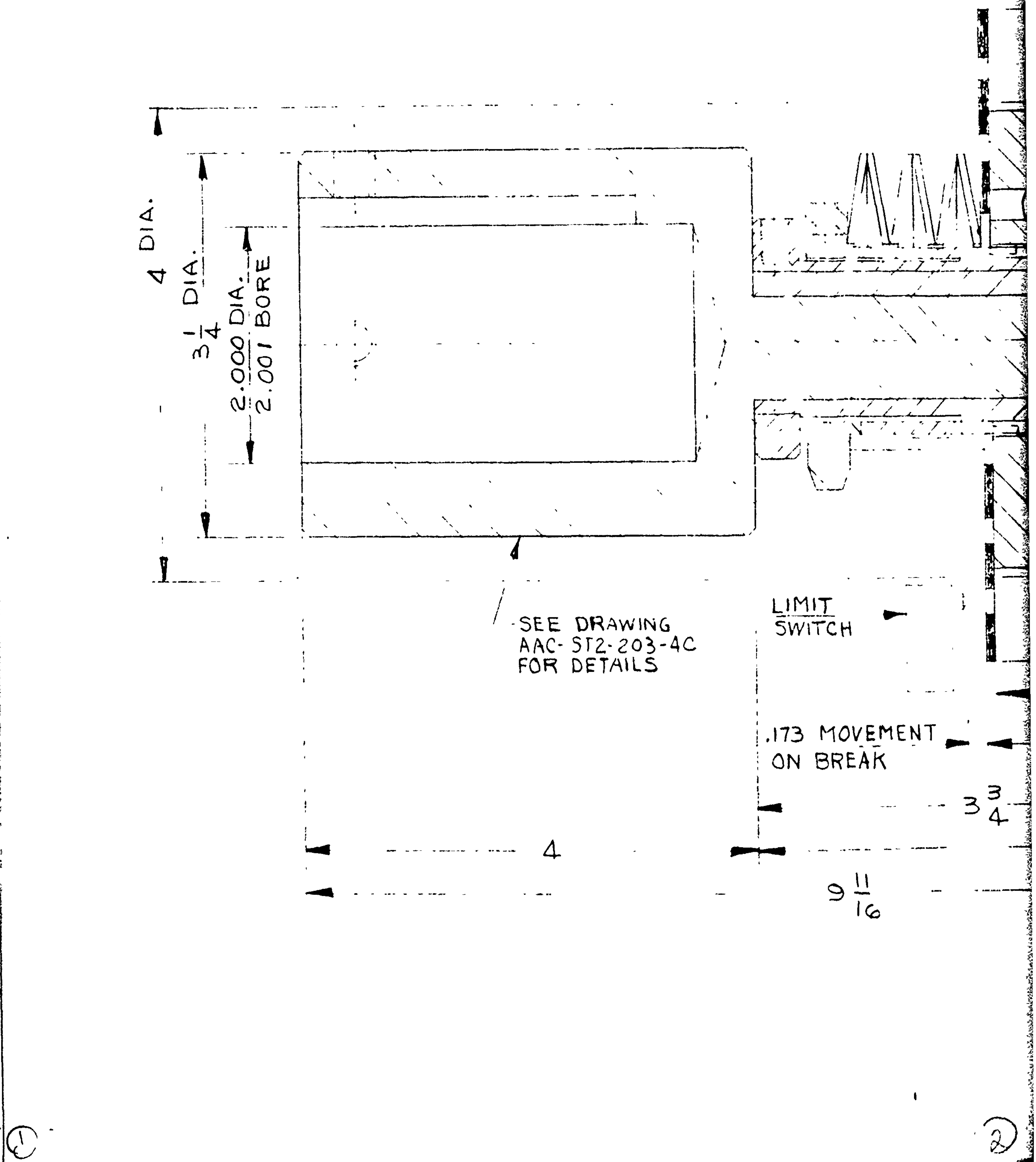
(b) Thrust bearing equipped with grease fitting for lubrication.

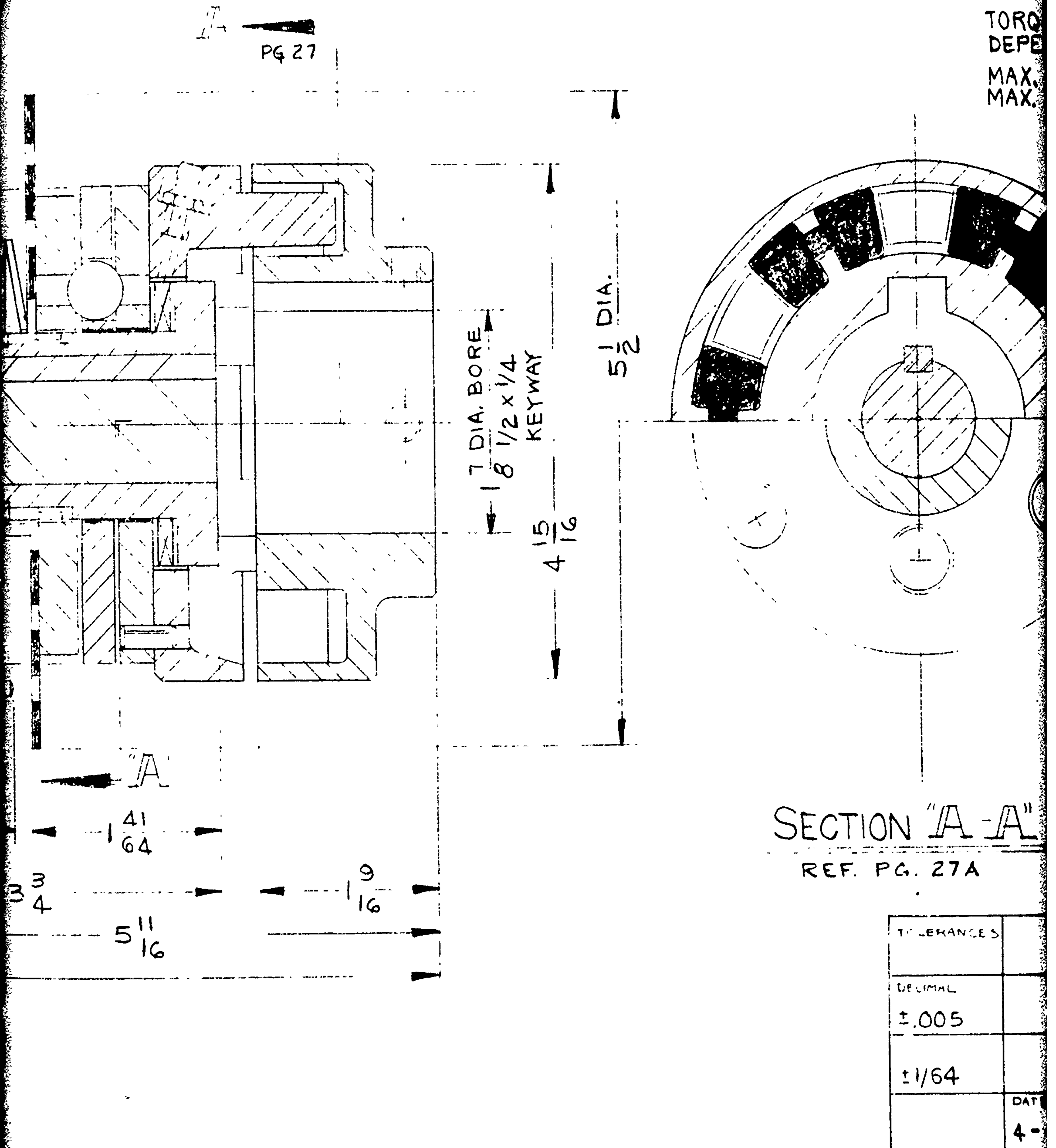
(c) Torque setting accuracy ± 10% of setting.

(d) Standard finish is black oxide. However, unit can be furnished cadmium plated.

(e) Using an adapter on the overload half permits coverage of maximum bore requirements.

4.6.7 The operating speed of 1750 RPM is beyond Autogard's normally recommended limit of 600 RPM. However, they feel the unit will provide satisfactory service and their normal parts and workmanship warranty will not be affected by the operating speed. Autogard's after thoughts recommend that a test under simulated operating conditions be mad^ to verify the above statement. They also advise the use of a brake on the motor side if possible.


4 DIA.
3 1/4 DIA.
2.000/2.001 DIA. BORE
SEE DRAWING AAC-ST2-203-4C FOR DETAILS
LIMIT SWITCH
.173 MOVEMENT ON BREAK
3 3/4
4
9 11/16
1
2



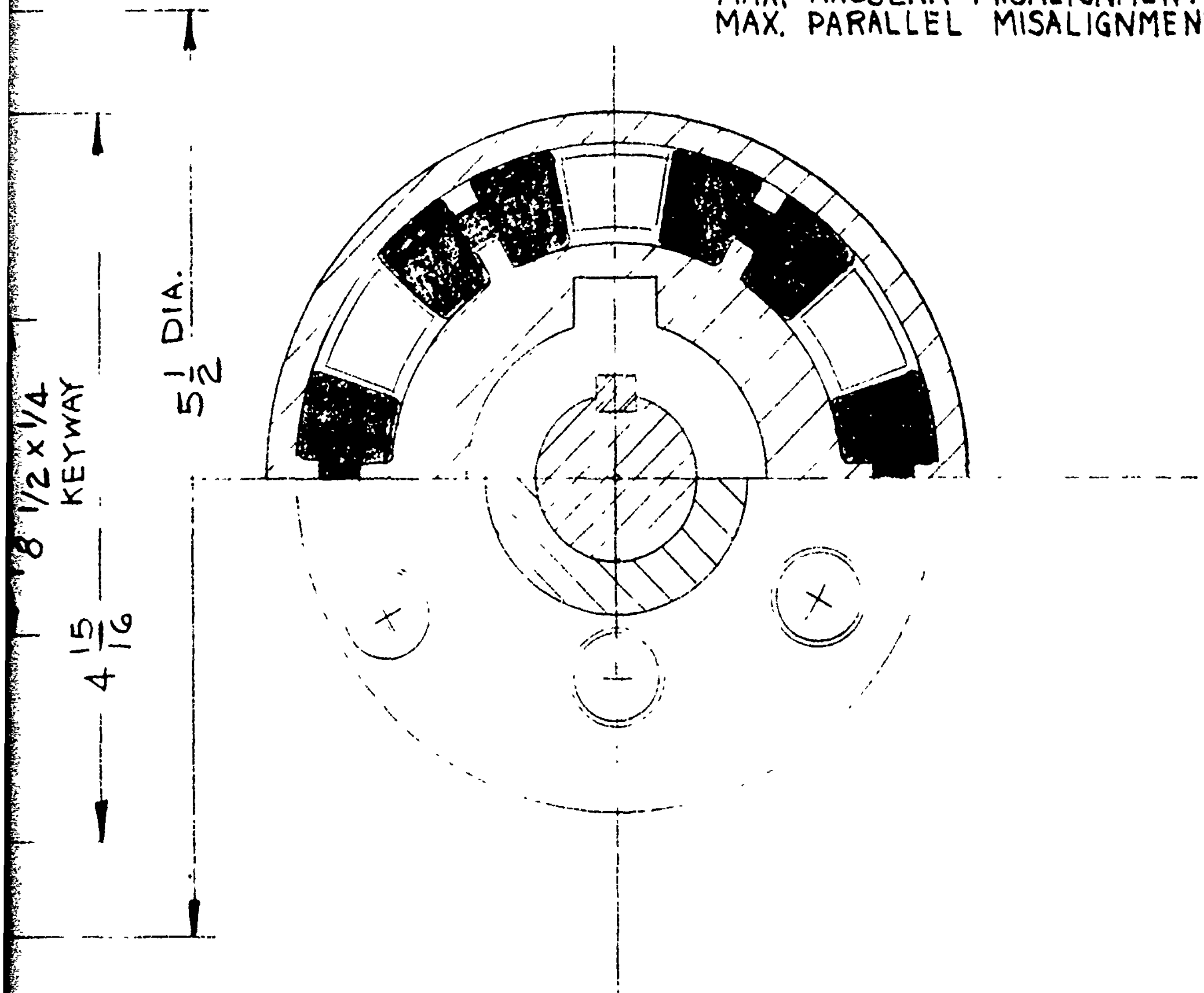
"A"
PG 27
TORQ
DEPE
MAX.
MAX.
1 7/8 DIA. BORE
1/2 x 1/4 KEYWAY
5 1/2 DIA.
4 15/16
"A"
1 41/64
3 3/4
1 9/16
5 11/16
SECTION "A-A"
REF. PG. 27A
TOLERANCES
DECIMAL
±.005
±1/64
DAT
4-

PG 27A

(3)

TORQUE RANGE 20-1451 LB IN.
DEPENDING ON SPRING INSTALLED

MAX. ANGULAR MISALIGNMENT 0°-24'
MAX. PARALLEL MISALIGNMENT .032



SECTION "A-A"

REF. PG. 27A

TOLERANCES	AAC AMERICAN AUTOGARD CORP		
DECIMAL ±.005		SCALE FULL	DRAWN BY T. KRAIMER
±1/64	MODEL 206N/ACT/2 TORQUE LIMITER WITH SPECIAL ADAPTOR		
	DATE 4-4-77	AAC-206N/ACT/2/03	

27A

AMERICAN AUTOGARD CORP.

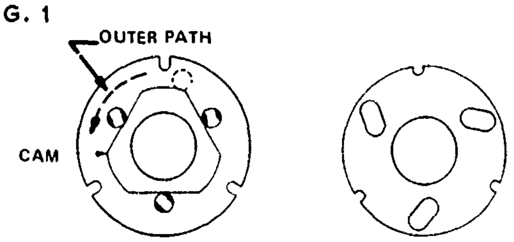
P.O. BOX 386
MENOMONEE FALLS, WISCONSIN 53051
PHONE: (414) 251-0085
TELEX 26795

INSTALLATION AND MAINTENANCE DATA

AUTOGARD TORQUE LIMITER

BALL TYPES

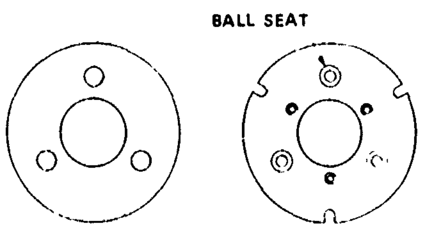
FIG. 1



"AF" DRIVE PLATE WITH CAM "AF" ENGAGING PLATE

TYPE "AF" (FREEWHEELING): Figure 1
This ball type consists of balls held in ball seats, located in the drive and slide plates. A 3, 6 or 9 lobe cam attached to the drive plate rolls the balls to an outer path when a torque overload occurs. The balls then roll without encountering ball seats. A plate with elongated slots permits engaging the unit by guiding the balls back into the seats.

FIG. 2



"AC" CAGE PLATE "AC" DRIVE PLATE

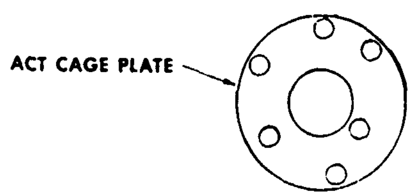
TYPE "AC" (CLANGER): Figure 2
This ball type differs from the "AF" type in that the balls are not cammed outward during a torque overload. They roll at the pitch diameter of the ball seats and drop into the seats as they are encountered. This re-engagement is quite audible (hence the reference to the unit as a clanger). In the "AC" ball type, there is no cam. The engaging plate is replaced by a slightly thicker cage plate which assures that the balls are held in proper position.

WARNING: The ratcheting action which occurs with the "AC" ball types can be damaging to the unit. Use of the "AC" ball type is not recommended when:

1. Shaft speeds exceed 100-200- RPM or
2. Unit will run, disengaged, more than 5-10 seconds.

Consult factory for assistance if these factors cannot be avoided because certain steps, such as operating the unit in oil, can be taken to avoid damaging the torque limiter.

FIG. 3



TYPE "ACT" (single position reset): Figure 3
The "ACT" ball type automatically resets each time in the same position for drives requiring synchronization. The balls are scattered on different diameters so that when an overload occurs the balls must return to their original positions before they re-seat Engagement will occur after two revolutions in either direction.

WARNING: The same restrictions as for the "AC" type above apply, except that the "ACT" type may run at speeds up to 400-600 RPM.

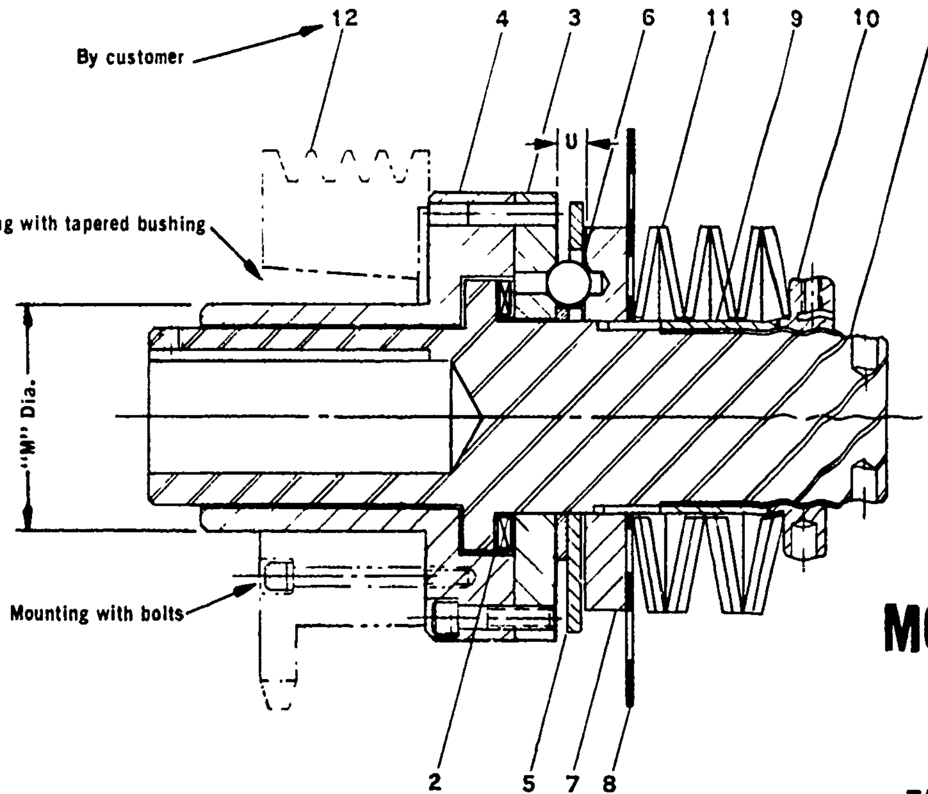


FIG. 4

MODEL 201

TABLE 1

Size	Dimension "U"	"M" Dia.
1	5/32 in.	1-1/4 in.
2	5/16	2
3	5/16	2-1/2
4	13/32	3-1/2
5	1/2	5

When unit is fully engaged.

LIST OF PARTS

1. HUB
2. NEEDLE BEARING
3. DRIVE PLATE & CAM
4. ADAPTOR (MODEL 201)
5. ENGAGING PLATE
6. BALLS
7. SLIDE PLATE
8. LIMIT SWITCH PLATE
9. SPACERS
10. ADJUSTING NUT
11. SPRING
12. SPROCKET OR PULLEY

COUPLING PARTS
SEE PAGE 5

13 COUPLING HUB (MODEL 204)
14 COUPLING HUB (MODEL 205)
15 ADAPTER (MODEL 205)
16 COUPLING HUB (MODEL 206N)
17 ADAPTER (MODEL 206N)

MODEL 202

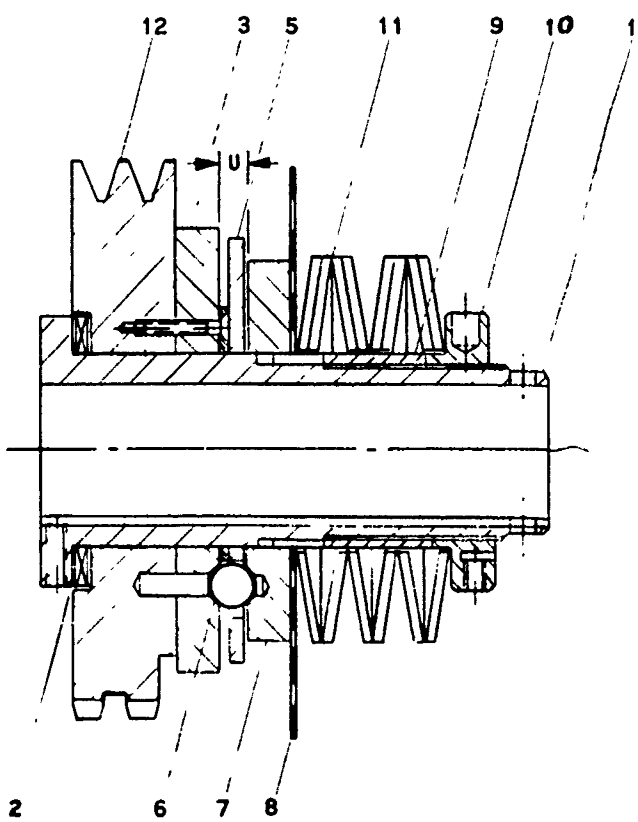


FIG. 5

PRIOR TO INSTALLATION

1. Mounting Sprocket or Sheave on Model 201.

A. Mounting with tapered bushings (taper-lock; Q-D; Browning; etc.):
Sprockets, sheaves and timing belt pulleys may be mounted directly on Model 201 Autogard by using taper-lock bushings. Select a sprocket with a bushing to fit "M dia." of the Autogard (Fig. 4). No key is used with these bushings when mounting on the Autogard. Be certain that the bushings are properly mounted and tightened per the instructions accompanying each bushing. Thoroughly clean all grease and oil from "M dia." with solvent prior to mounting the bushing.
NOTE: Check that adaptor and bushing assy. is free to turn on hub after bushing has been fully tightened.

B. Mounting with bolts:
Sprockets, flat sheaves, etc. may also be mounted on Model 201 Autogard by bolting as shown in Fig. 4.
The adaptor, item 4, must be removed for drilling and tapping the mounting holes (Table 2) if they were not ordered with the unit (see Disassembly Procedure page 7).

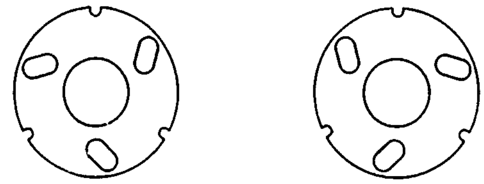
Attach sprocket, etc., onto adaptor prior to reassembly and inspect to insure that there are no protrusions inside the adaptor which might interfere with the hub. The unit may then be reassembled for use.

2. Direction of the slots ("AF" Type):
The direction of the slots in the "AF" engaging plate has no effect on the tripping action of the torque limiter. The Autogard will trip in both directions no matter which way the slots point. The directions of the slots can be important in resetting when neither side of the drive can be manually advanced or can be advanced in one direction only. A simple bench test will show the proper assembly for a particular drive. If a bench test is not feasible, figure 6 will show proper assemblies.

ROTATION OF DRIVEN PLATE

CW SLIDE PLATE
CCW DRIVE PLATE

CW DRIVE PLATE
CCW SLIDE PLATE



BOTH VIEWED FROM SPRING SIDE

FIG. 6

3. Number of balls:
Check to see if the proper number of balls are in the unit per Table 3. When changing from a coil spring to a disc spring, it will be necessary to add balls. The balls are standard ball bearing balls and can be obtained from distributor.

TABLE 3

UNIT SIZE	BALL DIAMETER	NUMBER OF BALLS		
		AF TYPE		AC TYPE
		COIL SPRING	DISC SPRING	COIL OR DISC SPRING
1	1/4	3	—	3
2	1/2	3	3	3
3	1/2	3	6	6
4	5/8	3	6	6
5	3/4	3	9	9

4. Proper spring:
Check to see that the spring will provide the desired range to release torque (Table 4). DO NOT TIGHTEN THE SPRING BEYOND ITS MINIMUM OPERATING LENGTH (with the torque limiter engaged) or the spring will not allow sufficient movement of the slide plate to let the balls leave their seats during an overload. Damage to the machinery or to the Autogard will result.

TABLE 2

RECOMMENDED HOLE PATTERNS ARE AS FOLLOWS:

AUTOGARD SIZE	NO. OF BOLTS*	BOLT SIZE	MAX. BOLT ENGAGEMENT IN ADAPTOR	BOLT CIRCLE DIAMETER	SPROCKET BORE
1	6	:8-32	.267	1-5 8	1.252 1.253
2	6	:8-32	.194	2-3 8	2.002 '2.003
3	6	1 4 x 20	.360	3	2.502 2.503
4	6	5 16 x 18	.479	4-1 8	3.5025 3.5035
5	6	3 8 x 16	.610	5-11 16	5.0025 5.0035

*Bolt holes to be equally spaced on bolt circle diameter specified. Care must be taken not to drill into other mounting holes in the adaptor.

TABLE 4

SIZE	SPRING					TORQUE RANGE		MIN. OPERATING LENGTH	
	TYPE	CODE	COLOR	QTY.	STACK AS	LB. IN.	KG. M.	IN.	MM.
1	coil	1C/1	white & red	1	fig. 7	20-250	.23 - 2.8	.95	24.2
	coil	1C/2	white & green	1	fig. 7	10-130	.12 - 1.4	.93	23.6
	coil	1C/3	white & yellow	1	fig. 7	5-60	.06 - .69	.74	18.8
2	disc	2D/1/S	blue & black	6	fig. 8	500-2000	5.7 - 23	1.00	25.4
	coil	2C/1	blue & red	1	fig. 7	120-650	1.4 - 7.5	1.08	27.8
	coil	2C/2	blue & green	1	fig. 7	50-400	.57 - 4.6	1.05	26.9
	coil	2C/3	blue & yellow	1	fig. 7	20-130	.23 - 1.4	.98	24.9
3	disc	3D/1/D	brown & black	8	fig. 10	1400-6000	16.1 - 69	1.15	29.4
	disc	3D/1/S	brown & black	6	fig. 8	600-3600	6.9 - 41	.88	22.3
	coil	3C/1	brown & red	1	fig. 7	400-2500	4.6 - 28	1.55	39.7
	coil	3C/2	brown & green	1	fig. 7	100-1200	1.1 - 13	1.49	38.0
	coil	3C/3	brown & yellow	1	fig. 7	40-500	.46 - 5.7	1.46	37.1
4	disc	4D/1/S	orange & black	5	fig. 9	2400-10,000	27 - 115	1.25	31.8
	disc	4D/2/S	orange	6	fig. 8	1200-7500	13.8 - 86	1.28	32.5
	coil	4C/1	orange & red	1	fig. 7	250-2800	2.9 - 32	2.00	50.8
5	disc	5D/1/S	grey & black	6	fig. 8	5500-22,500	63 - 259	2.38	60.4
	disc	5D/2/S	grey	6	fig. 8	3000-20,000	34 - 230	1.97	50.1
	coil	5C/1	grey & red	1	fig. 7	350-3100	4 - 35	1.75	44.5

FIG. 7

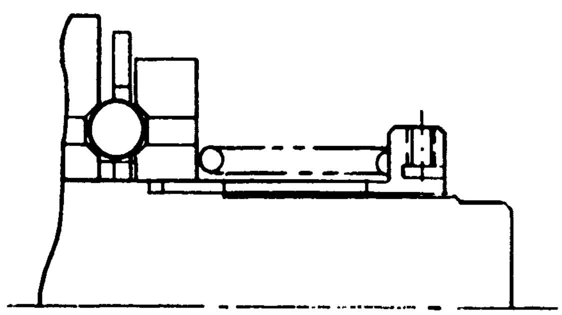


FIG. 8

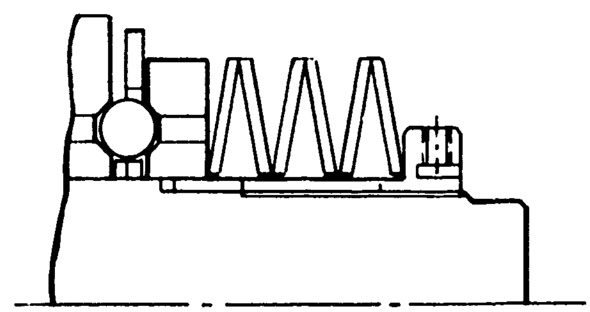


FIG. 9

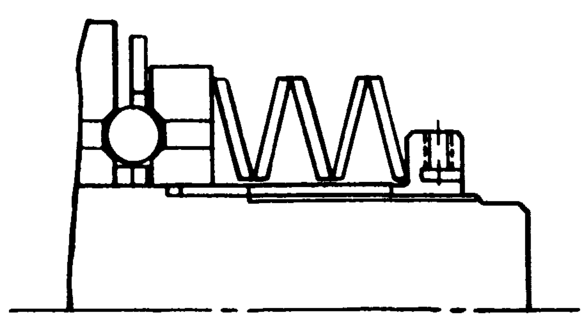
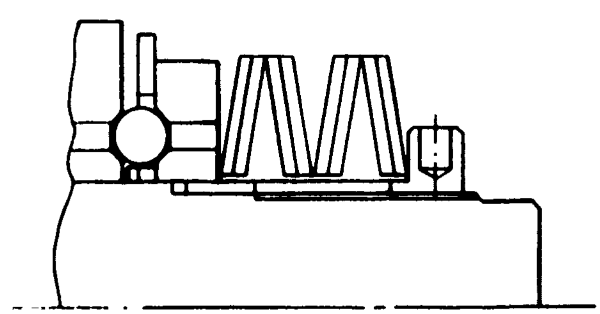


FIG. 10



5. Calibration spacers:

Calibration spacers perform two functions:

A. Maintain proper stacking of disc springs.

B. Prevent unauthorized tightening of the adjusting nut.

Calibration spacers are normally supplied in several segments to allow upward adjustment of the unit in the field. The bottom segment is for the minimum length of the spring being used. This segment should not be removed. If a higher release torque is required, use a stronger spring. Units shipped from the factory, set at a specified torque, have spacers which will allow adjustment to about 125% of the set torque before removal of segments becomes necessary.

6. Lubrication:

The needle bearing, plate faces and balls should be well lubricated with a good grade grease, equivalent to specification MIL-G-3545-13.

A grease nipple is provided on units larger than size 1 to allow greasing of the needle bearings. SAE 30 oil is to be used on size 1 which has an oiling hole instead of a nipple.

INSTALLATION

1 Models 201 & 202
Figs. 4 & 5, Pg. 2

MOUNTING THE AUTOGARD TORQUE LIMITER ON THE SHAFT

Mount the torque limiter by engaging the hub on the shaft. The unit may be moved axially on the shaft to a degree to obtain proper alignment of the sprocket or sheave with the chain or belt. The minimum acceptable shaft engagement is 1½ times the shaft diameter. Tighten the set screws fully. Recommended torque values for set screws are shown in Table 5.

See pg. 2 for parts list.

TABLE 5

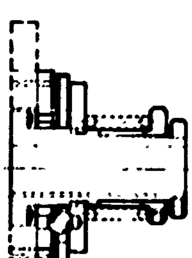
SETSCREW SIZE	#10	1/4	5/16	3/8	7/16	1/2
SEATING TORQUE INCH/LB.	33	87	165	290	430	620

2.
MODELS 203 *, 204, 205, 206N
FIGS. 11, 12, 13, & 14 Below

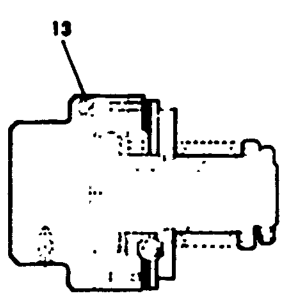
Mount the torque limiter hubs to the shafts same as per instructions for models 201 & 202 on this page. Table 7 shows the maximum allowable misalignment for optimum unit life. See pg. 2 for parts list. Parts numbered 1-11 are same for all models.

TABLE 6

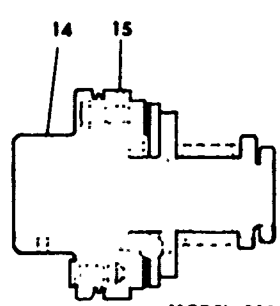
Model	Size	Allowable Angular Misalignment	Allowable Parallel Misalignment	Gap between hub and adaptor	
				Min.	Max.
203*	1-5	0	0		
204	1-5	0	0		
205	1	.5 deg.	0		
	2	.5 deg.	0		
	3	.5 deg.	0		
	4	.5 deg.	0		
	4	.5 deg.	0		
	5	.5 deg.	0		
206N	1	.4 deg.	.016"	5/64"	5/32"
	2	.4 deg.	.016"	5/64"	5/32"
	3	.4 deg.	.016"	5/64"	5/32"
	4	.4 deg.	.032"	5/64"	1/4"
	5	.8 deg.	.032"	1/8"	5/16"



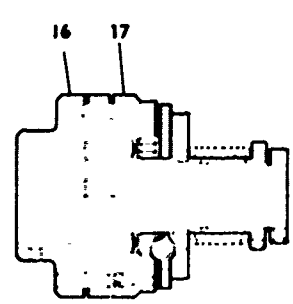
MODEL 203
FIG. 11



MODEL 204
FIG. 12



MODEL 205
FIG. 13



MODEL 206N
FIG. 14

• For model 203 the driven member is supplied by customer. If used for offset drive the pulley, gear, etc. must be mounted on its own bearing.

LIMIT SWITCH OPERATION:

Limit switches are easily used to give a warning or shut down a drive in the event of a torque overload. The limit switch is actuated by the movement of the slide plate (or the limit switch plate when used). See Table 7 for guidelines. Always use limit switch with "AC" and "ACT" types.

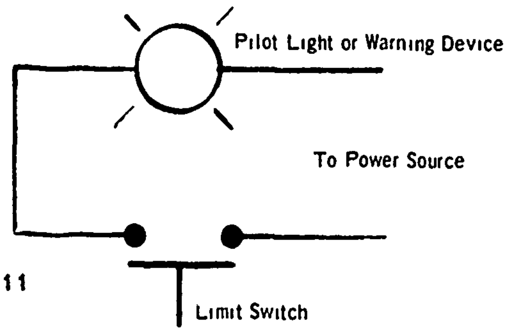


FIG. 11

Size	Movement on break 'X' (inches *mm*)	Ball plate dia. 'D' (inches *mm*)	Plate dia. 'E' (inches *mm*)
1	·095 *2·4*	2 *51*	3¼ *83*
2	·173 *4·4*	3½ *89*	5½ *140*
3	·173 *4·4*	4¼ *108*	6½ *165*
4	209 *5·3*	5⅞ *149*	8 *203*
5	·248 *6·3*	8 *203*	10 *254*

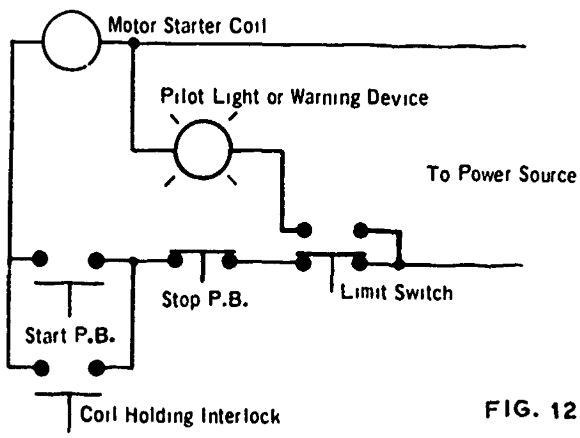


FIG. 12

TABLE 7

MANUFACTURER	CATALOG NO.	RATING VOLTS AC MAX.	RATING AMPS MAX.	ENCLOSURE	CONTACT TYPE
ALLEN BRADLEY	802R-DF	250	5	NEMA 12	SPDT
ALLEN BRADLEY	802T-D	600	10	NEMA 12	SPDT
GENERAL ELECTRIC	CR9440 K1M1	600	10	NEMA 12	SPDT
GENERAL ELECTRIC	HO1308	575	10	NEMA 12	SPDT
MICRO-SWITCH	5LS1	480	10	NEMA 4	SPDT
MICRO-SWITCH	15LS1	240	10	NEMA 4	DPDT
MICRO-SWITCH	BZE6-2RN80	480	15	NEMA 2	SPDT
MICRO-SWITCH	OP-AR30	480	15	NEMA 4	SPDT
MICRO-SWITCH	EX-AR30	480	15	NEMA 9	SPDT
MICRO-SWITCH	205LS1 (PLUG IN)	480	10	NEMA 4	SPDT
ALLEN BRADLEY	802-PASJ203	600	5	OPEN	SPDT
GENERAL ELECTRIC	CR115JB0201	575	10	OPEN	SPDT
MICRO-SWITCH	BZE6-2RQ8	480	15	OPEN	SPDT
MICRO-SWITCH	BZ-RW922T	480	10	OPEN	SPDT
MICRO-SWITCH	BZ-2RQ18T	480	15	OPEN	SPDT
CUTLER-HAMMER	SS12ET10-102L3	250	15	OPEN	SPDT
CUTLER-HAMMER	SS12BT10-102L3	250	10	OPEN	SPDT
CHERRY	E23-OOK	250	5	OPEN	SPDT
CHERRY	E33-OOK	250	10	OPEN	SPDT
CHERRY	E34-OOK	250	15	OPEN	SPDT

INITIAL STARTUP

Prior to startup, examine unit to assure it is engaged, i.e., balls are seated fully in both plates. When fully engaged, dimension between the drive plate and slide plate is per Table 1.

Obtain the initial torque setting by one of the following methods:

1. Setting torque with unit installed:
   Start up the drive with a low torque setting and progressively tighten the adjusting nut until the unit will start and drive under normal load without tripping. Peak starting torque is usually the highest torque which the torque limiter must transmit, but occasionally the torque limiter must be set to accommodate higher peak torques.

2. Testing with spring scale and lever arm (may be done on a bench or after unit is mounted in drive).
   If the unit is mounted, be certain that one side of the limiter or drive is disconnected and free to rotate. The other side must be held stationary. An example of a bench test is shown in figure 13. The spring scale is pulled until the unit trips. Take care to maintain a slow steady pull, keeping the pull on the spring scale at 90° to the arm, and keep the arm approximately vertical or the reading will be affected by the arm weight. Carefully note the load on the spring scale at which the unit trips. The corresponding torque is this load multiplied by the length of the arm ("L") measured to the point of pull. Adjust the position of the adjusting nut until the correct torque setting is reached. Do not confuse lb. inches and lb. feet. When working in lb. inches it is convenient to make the arm 10" so that the load in pounds x 10 = torque in lb. inches. Similarly, when working in lb. feet, an arm of 1 foot will give a spring scale reading directly in lb. feet (i.e. load x 1).
   For high torque on the larger units a longer arm will be necessary to avoid excessively high spring scale loads. For example, 2,000 lb. inches would require 200 lb. load on a 10 inch arm, but only 50 lb. on a 40 inch arm.

3. Unit set at factory:
   When a torque setting is specified in the order, the unit is set at the factory within ±10%. If the unit must be disassembled, note the spring compressed length prior to disassembly and adjust to that length upon reassembly to obtain the desired torque.

CAUTION: Do not tighten spring beyond its minimum operating length. See Table 4.

TESTING & TORQUE SETTING

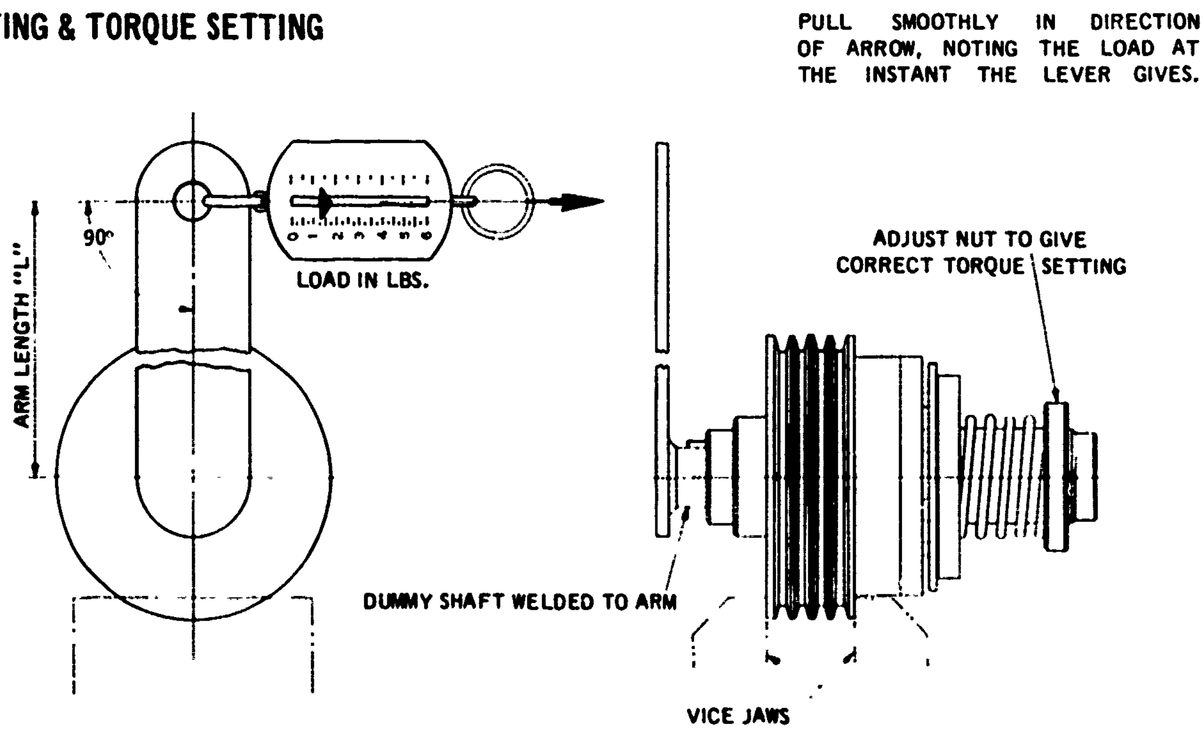


FIG. 13

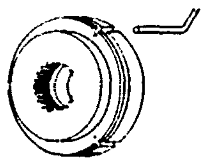
RESETTING PROCEDURE

1. Shut down drive.
2. Investigate and remove cause of overload or jam.
3. Reset:

A. "AF" Type

Rotate either side of the drive until a slot on edge of the engaging plate aligns with a slot in the drive plate, and lock these two plates in this position with a bar in the slots (fig. 14).

FIG. 14



Note that these slots are not to be confused with those in which the balls run. Further rotation of either side of the drive approximately 80 degrees will give engagement if the correct direction of rotation is selected, (see Direction of Slots) and balls can be heard to re-engage with their seatings quite distinctly. Insure that the resetting bar is removed before resetting the drive. To check full engagement, see Table 1.

B "AC" Type:

It is likely that the unit stopped in the engaged state. Rotation of either side of the drive for a maximum of 240 degrees will re-engage the unit. To check full engagement, see Table 1.

C. "ACT" Type

Rotation of either side of the drive for a maximum of 720 degrees will re-engage the unit. To check full engagement, see Table 1.

DISASSEMBLY PROCEDURE

NOTE: Measure spring length before disassembly.

A. With spring end up remove adjusting nut, spring, spacers, limit switch plate, slide plate, engaging plate & balls.
B. Gently drive pins from adaptor & drive plate.
C. Remove cap screws and gently work drive plate over spline so as not to damage bearing material on I.D. of plate.
D. Remove adaptor carefully so as not to damage bearing material on I.D.
E. Inspect the bearing surfaces prior to reassembly and carefully blend out any scratches.
F. Apply a liberal coating of a good grade machine oil (SAE 30) to the I.D. of the adaptor or drive plate and engaging or cage plate prior to reassembly.
G. For reassembly, reverse steps A thru D.

NORMAL MAINTENANCE

The autogard torque limiter should be greased regularly when the equipment on which it is mounted is maintained. Maximum time between inspection and maintenance is 2000 hours operation or after each disengagement, whichever is sooner. For unusual conditions, such as very high RPM, high ambient temperatures, high vibration or dirty environments, special maintenance may be required.

Inspect for sprocket wear, tightness of limiter on its shaft, tightness of sprocket, etc. at this time.

TABLE 8

PROBLEM	PROBABLE CAUSE	CORRECTIVE ACTION
Autogard will not drive	Machine jammed	Carefully inspect machine for signs of jamming, and clear.
	Torque setting to low	Increase torque setting by tightening adjusting nut, removing calibration spacer segments as necessary. Do not tighten beyond minimum spring length (see table 4). Use stronger spring or larger size units if necessary.
One or more balls will not reset on "AF" ball type or one or more balls will not leave ball seat.	Improper number of balls.	Check the number of balls in the unit against table 3.
	Insufficient spring pressure	Check to be certain that spring is not completely loose when Autogard is engaged. If so, use weaker spring or smaller size Autogard.
		If 6 balls are being used (with disc springs), try increasing torque by 1 or 2 turns. If this corrects problem, reduce number of balls to 3. If problem continues, warped plate could be responsible.
	Warped plate	same as insufficient spring pressure.
		Replace plate. To confirm that plate is warped, inspect faces where balls contact. Ball path should be visible, but should not have appreciable depth. Surfaces of plate to be flat within .002 T.I.R.
Will not rotate freely when disengaged.	Lacks lubrication	Lubricate with grease equivalent to specification MIL-G-3545-13. A good grade machine oil can be applied to the hub to work into the resin bonded bearing.
	Slight eccentricity of internal bearing surfaces.	Lubricate well and rotate hub within unit for 200 to 300 revolutions.
	Scratch on internal bearings.	Disassemble and inspect. Carefully blend out any blemishes. Lubricate well upon reassembly.

4.7 Ferguson Machine Rite-Torq Torque Limiter, Ref. Fig. #8

4.7.1 Rite-Torq offers a newly developed mechanical torque limiter which is a takeoff from their AS-20 light duty unit, using the same basic principle of torque transmittal, with a greater range.

4.7.2 The basic unit selected for this application is a Type "S" Size 2 unit which resets automatically with a torque range up to 520 Lb. In. and is externally adjustable.

4.7.3 With the tripping components made from heat treated chromium alloy steel, standard units have been subjected to 50,000 trip cycles under design loading with negligible wear.

4.7.4 Other features included in the standard basic unit are,

(a) Bi-directional operation

(b) All position mounting

(c) Fully enclosed

(d) Lubed for life

(e) Protected against corrosion

(f) Setting accuracy ± 5%

(g) Locking ring tab for maintaining setting

(h) Limit switch operation up to 2000 RPM

4.7.5 When a limit switch is used with a totally enclosed unit, a trip plate must be added to provide clearance for the limit switch actuating arm and the spring cover.

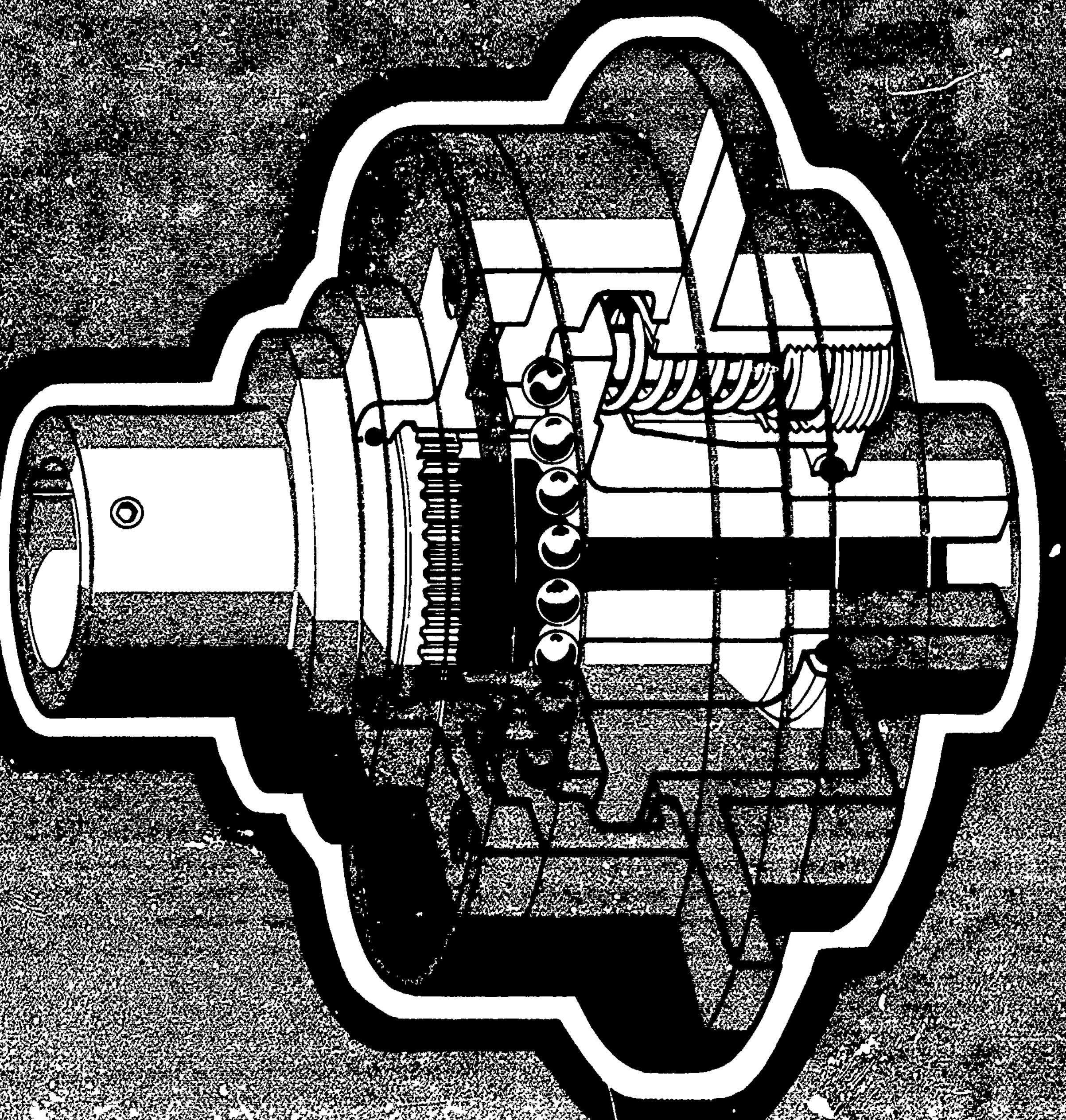
4.7.6 The clutch half of the unit has a maximum 1 1/8" bore and will require an adapter to accomodate the motor bore sizes of 1 5/8" and 1 7/8". The coupling half of the unit must be a flexible type to allow for shaft misalignment and also provide for a 2" maximum shaft size on the reducer. Figure 9 shows a roller chain flexible coupling mounted to the torque limiter, however, any type of flexible coupling may be used.

4.7.7 The manual reset pin (5) shown in Figure 8 is an added feature, making the unit more versatile. However, it is not considered to be a requirement on this application.

4.7.8 The setting torque accuracy is possible on request, by supplying each unit with an indicator plate or setting chart which allows the release torque to be set on site to any value within the unit's range with an accuracy of ± 5%.

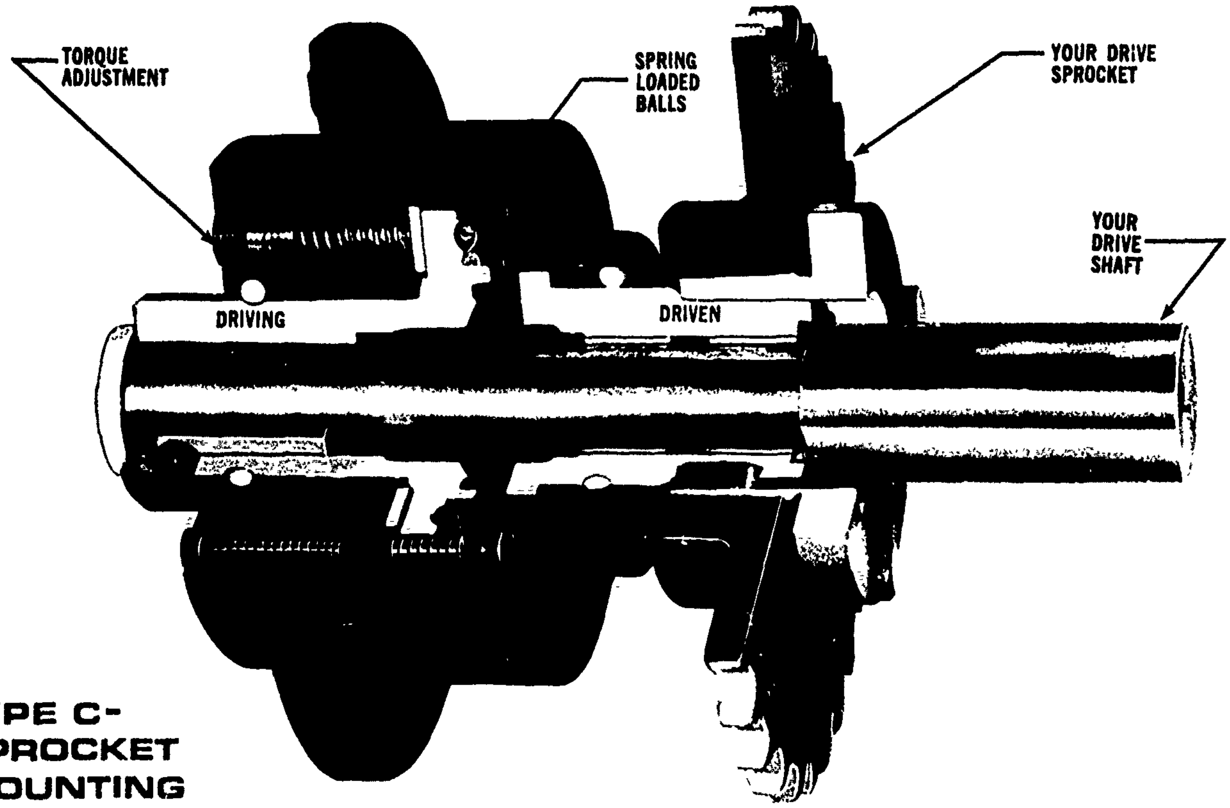
4.7.9 According to Rite-Torq, the ratcheting effect of the detented balls on disengagement has negligible wear on the tripping components and will reset under motor enertia when it becomes lower than the overload trip setting. The stopping time will be less than a free rotating motor due to the braking action of the torque limiter resetting or ratcheting.

FERGUSON



RITE-TORQ

OVERLOAD CLUTCH
FOR DEPENDABLE
MACHINE PROTECTION



TYPE C-
SPROCKET
MOUNTING

MECHANICAL OVERLOAD CLUTCH FOR PRECIS INSTANT RESPONSE.....AUTOMATIC RESET..

COMPLETE DEPENDABILITY

The Rite·Torq overload clutch protects your machine from damage by terminating power almost instantaneously when an overload·causing jam creates torque in excess of set limits. When the jam is cleared the Rite Torq resets automatically to resume operation, thus it is ideal for remote or inaccessible installations

Completely mechanical, the Rite·Torq maintains the precisely set tripping point regardless of speed, number of trips or ambient temperatures. Although you may specify a factory set tripping torque and never have occasion to change it, simple external adjustments can be made if desired to afford a wide range of torque protection.

MAINTENANCE-FREE

The Rite·Torq does not rely upon friction surfaces for its operating principle. Rite·Torq safety clutches transmit motion through balls retained in seats between driving and driven hubs. During an overload the hubs separate sufficiently to allow balls to roll from seat to seat under positively controlled pressure. With only rolling friction present, the Rite·Torq is subject to virtually no wear. Its rugged cast housing is sealed by O·rings against abrasive substances and moisture. Except in unusual circumstances, original factory lubrication need not be replenished.

EASILY INSTALLED

Each size unit has a nominal torque rating with a range of adjustments to approximately 50% above or 50% below. Ideally, tripping torque should be at least 40% greater than operating torque; "tripping torque" being the maximum torque load below which the Rite·Torq will transmit power without disengaging.

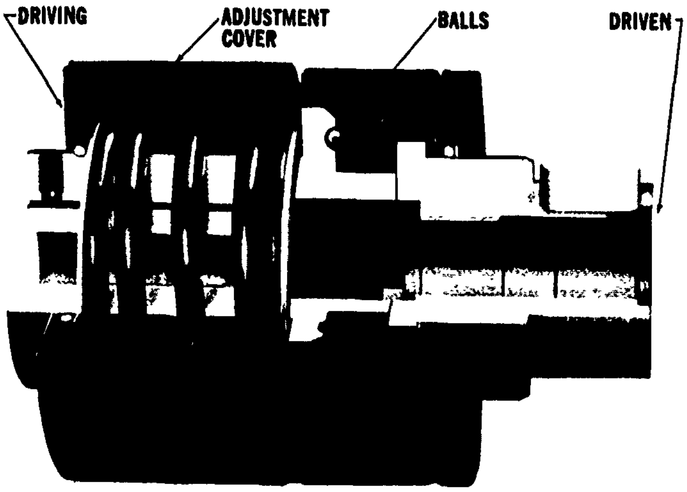
Preferred location for mounting a Rite·Torq is between the low speed side of the reducer and the driven machine or mechanism. Under adverse conditions caused by vibratory, intermittent or reversing loads we recommend that you consult a Ferguson representative or distributor for applications assistance.

FOR CHAIN, BELT AND DRIVEN MACHINES

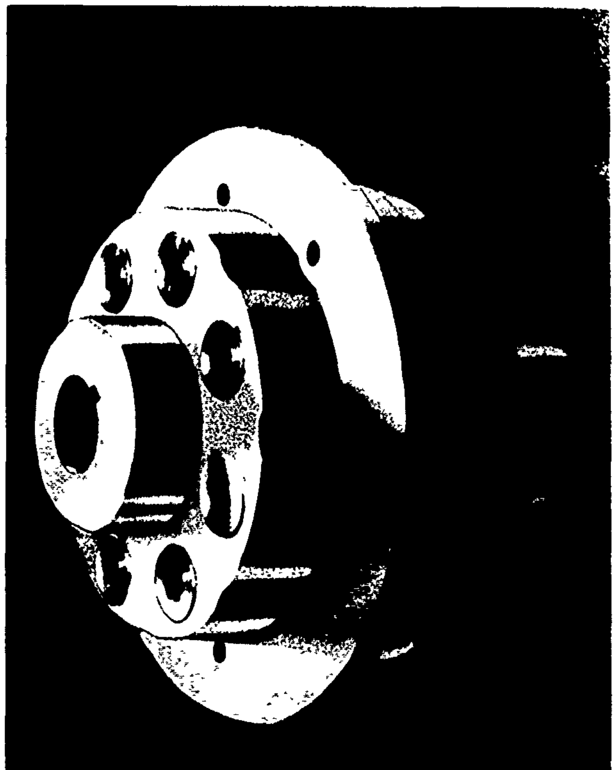
There are nine models for either sprocket (Type C) or coupling (Type S) mounting to provide tripping torques from 65 to 52,000 inch·pounds. They are furnished with stock bore diameters. Other bore diameters may be specified at a slight additional charge (See dimensional table).

SINGLE POSITIONING

Any of the models may be ordered with an optional single positioning feature which acts as a phasing mechanism to insure that your machine resumes cycling when the jam is cleared at the precise point where the interruption occured.



MODEL AS-20
LIGHT DUTY UNIT



TYPE S -
COUPLING MOUNTING

...E TRIPPING REGARDLESS OF SPEED.....
...EXTERNAL ADJUSTMENT.

SPECIFICATIONS **MOUNTING TOLERANCES: Angular 1° Total · Concentricity and Squareness .002" TIR.**

MODEL	TRIP TORQUE (In.-Lbs.)			MAX. RPM† WITH LIMIT SWITCH	NO. OF BALLS	INERTIA (WK^2)	WT. (LBS.)	BORE DIAMETER (Inches) +.001 −.000					
	NOM.*	MIN.	MAX.					STOCK				MIN.	MAX.
AS-20	130	65	195	1800	31	.028	10	.625	.750	.875	1.000	.56	1.00
AS-30	270	135	450	1800	28	.178	11	.750	.875	1.000		.56	1.00
● AM-60	800	400	1670	1800	36	.247	13	.875	1.000	1.125		.69	1.18
● AM-120	1620	825	2440	1800	44	.415	18	1.000	1.125	1.250		.75	1.38
AS-250	2170	1100	3125	1200	42	.83	28	1.250	1.375	1.500		1.12	1.75
AS-500	4335	2200	6760	1200	45	2.20	50	1.625	1.875	2.000		1.62	2.38
● AM-1000	12945	6450	20700	900	40	10.30	110	2.000	2.375			1.94	2.68
AS-2000	17240	8700	26500	900	44	22.50	180	2.500				2.38	3.38
AS-4000	34680	17000	52000	500	42	60.70	344	3.125	3.250			2.94	4.18

* Factory trip setting unless otherwise specified.
† Single positioning units have maximum speed of 100 RPM and require limit switch -- consult factory for higher speeds.
● AM Couplings are interchangeable dimensionally with AS Couplings having the same numerical designations but minimum and maximum tripping torques are approximately 50 percent greater. Lower tripping torques can be provided at slight additional charge.

STANDARD KEYWAY DIMENSIONS

BORE DIA. FROM	BORE DIA. TO	KEYWAY	BORE DIA. FROM	BORE DIA. TO	KEYWAY
.500	.563	1/8 x 1/16	1.813	2.250	1/2 x 1/4
.625	.875	3/16 x 3/32	2.313	2.750	5/8 x 5/16
.938	1.250	1/4 x 1/8	2.813	3.250	3/4 x 3/8
1.313	1.375	5/16 x 5/32	3.313	3.750	7/8 x 7/16
1.438	1.750	3/8 x 3/16	3.813	4.500	1 x 1/2

WHEN ORDERING

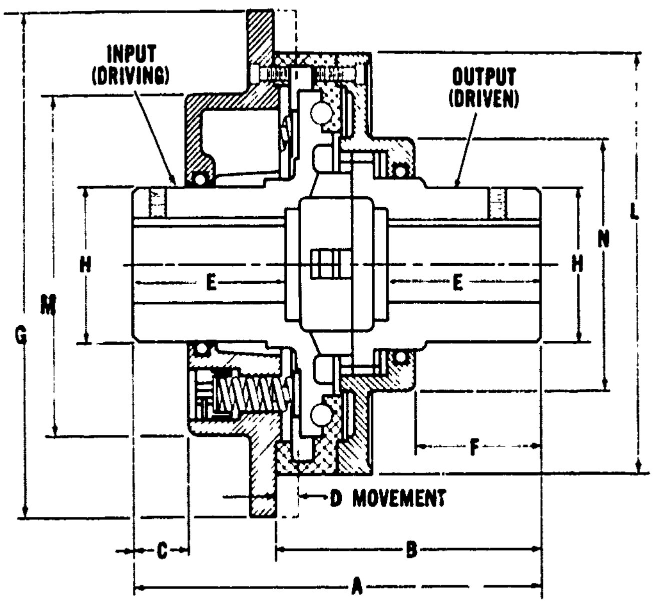
Specify Model number, Type S or Type C, bore dimensions and torque setting and indicate if optional single positioning is required.

TO DETERMINE TORQUE

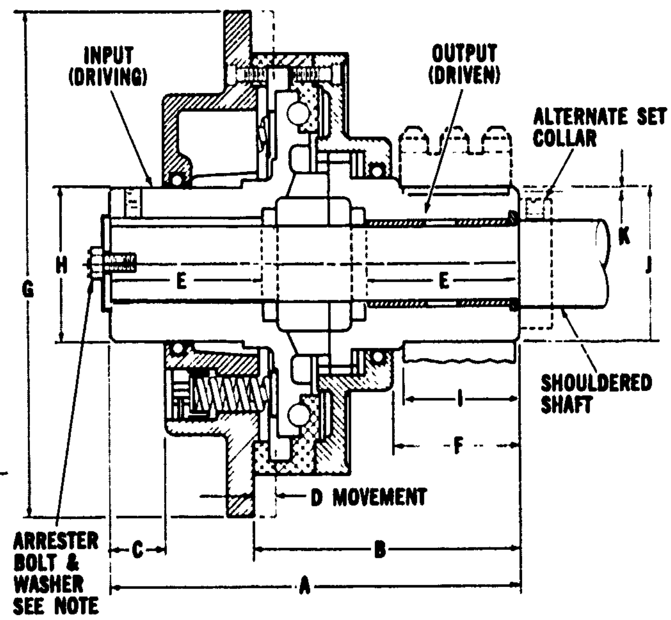
$$HP = \frac{\text{Torque(In.-Lbs.)} \times \text{RPM}}{63025} \quad \text{OR: Torque(In.-Lbs.)} = \frac{HP \times 63025}{RPM}$$

·R TRIPPING TORQUES FROM 135 TO 52,000 IN.-LBS.

TYPE S-COUPLING MOUNTING



TYPE C-SPROCKET MOUNTING



NOTE: If arrester bolt and washer (supplied by customer) cannot be used on Type C model install a set collar next to driving hub to prevent axial movement.

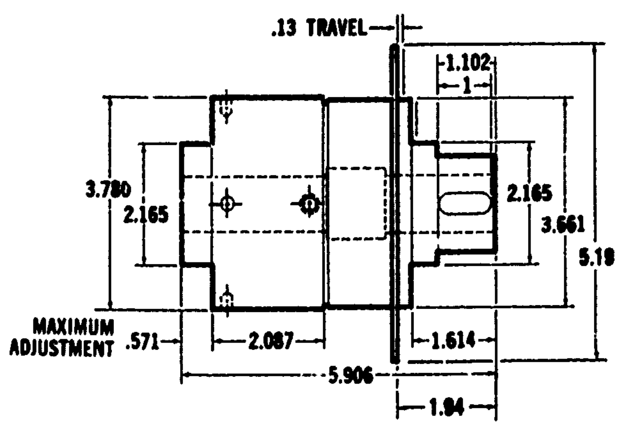
DIMENSIONS

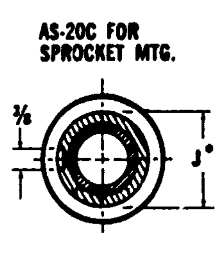
"D" is travel distance for limit switch actuation; for single positioning, couplings use D/2 (see back page). Special hub diameters between standard (max.) and minimum can be provided at slight additional charge. "K" is keyway dimension. A flat key meeting standard sprocket requirements is included.

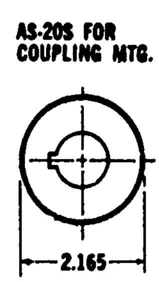
MODEL	A	B	C	D*	E	F	G	H	I	J (+.000 −.001) STD. (MAX.)	J (+.000 −.001) SPEC. (MIN.)	K*	L	M	N
AS-30	5.89	3.81	.80	.16	1.97	1.50	6.09	1.77	1.09	1.75	1.56	3/8 x 3/32	4.53	4.33	2.76
AM-60	6.30	4.14	.80	.16	2.36	1.83	7.00	2.00	1.50	2.00	1.75	1/2 x 1/8	5.43	4.09	3.07
AM-120	7.19	4.97	.80	.16	2.36	2.66	7.91	2.17	2.17	2.12	1.95	1/2 x 1/8	6.34	4.96	3.78
AS-250	7.64	4.97	1.02	.20	2.91	2.44	9.06	2.77	2.17	2.75	2.50	5/8 x 1/8	7.48	6.06	4.62
AS-500	10.34	7.00	1.38	.23	4.11	3.50	10.23	3.55	3.06	3.56	3.19	7/8 x 1/4	8.66	7.24	5.59
AM-1000	12.44	8.42	1.19	.34	4.11	4.34	13.66	4.12	3.34	4.12	3.88	1 x 5/16	12.09	10.08	7.88
AS-2000	15.75	11.14	1.38	.39	5.30	6.34	15.98	5.12	4.92	5.12	4.50	1 1/4 x 5/16	14.41	12.02	9.00
AS-4000	18.80	12.12	2.75	.52	5.30	6.53	18.91	6.69	5.31	6.69	5.88	1 3/4 x 3/8	17.17	14.17	11.25

MODEL AS-20 FOR LIGHT DUTY MACHINES

LIMIT SWITCH ACTUATING DISC IS AVAILABLE.

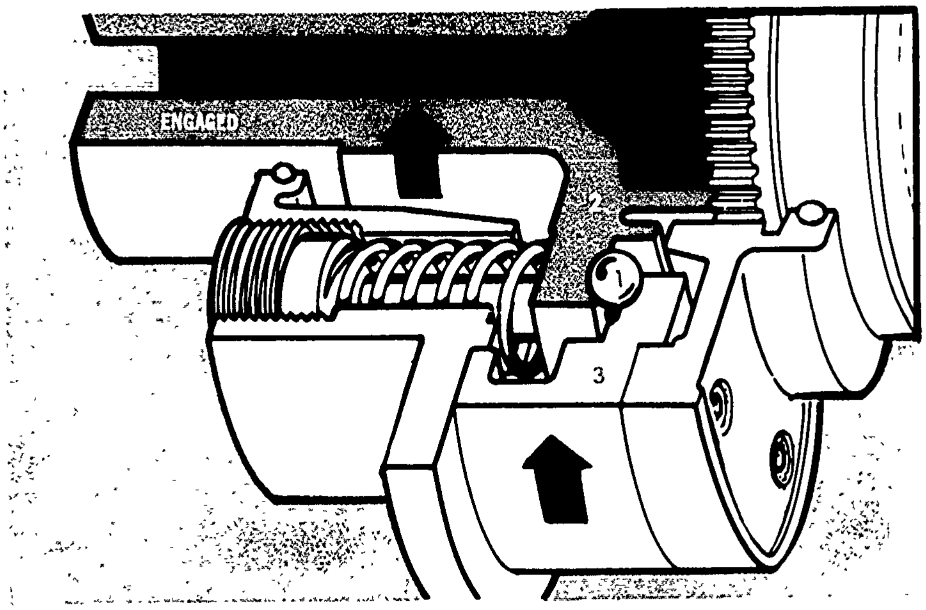


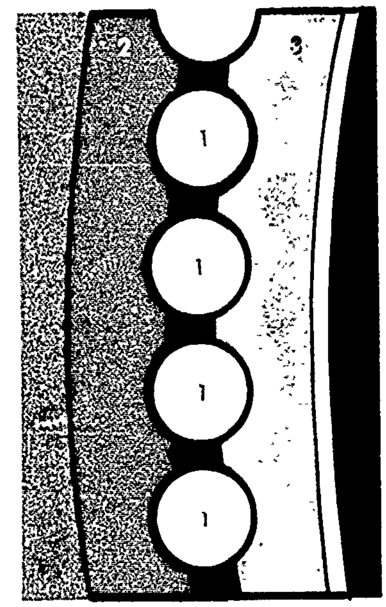


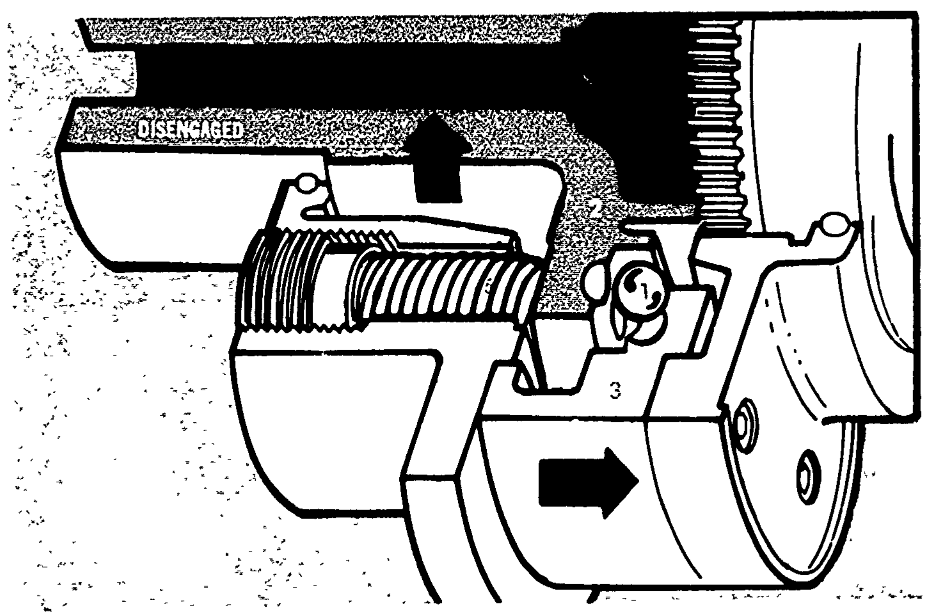


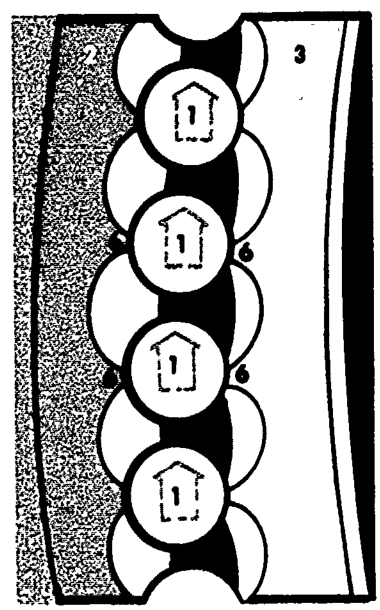
* The standard hub diameter (J Dimension) for the Model AS-20 is 1.75 inches. Other hub diameters from 1.44 to 2.00 inches may be ordered for a slight additional charge.

CONTROLLED BALLS TRANSMIT POWER BETWEEN TWO HUBS

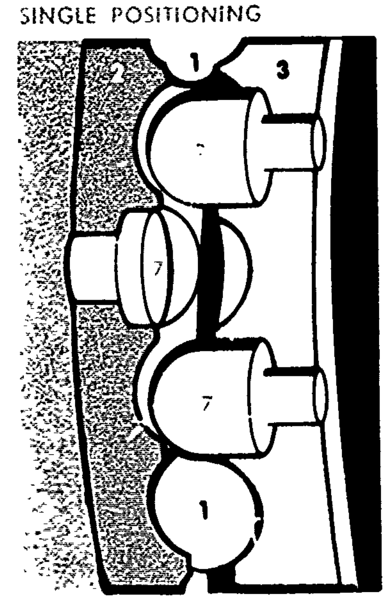








SINGLE POSITIONING



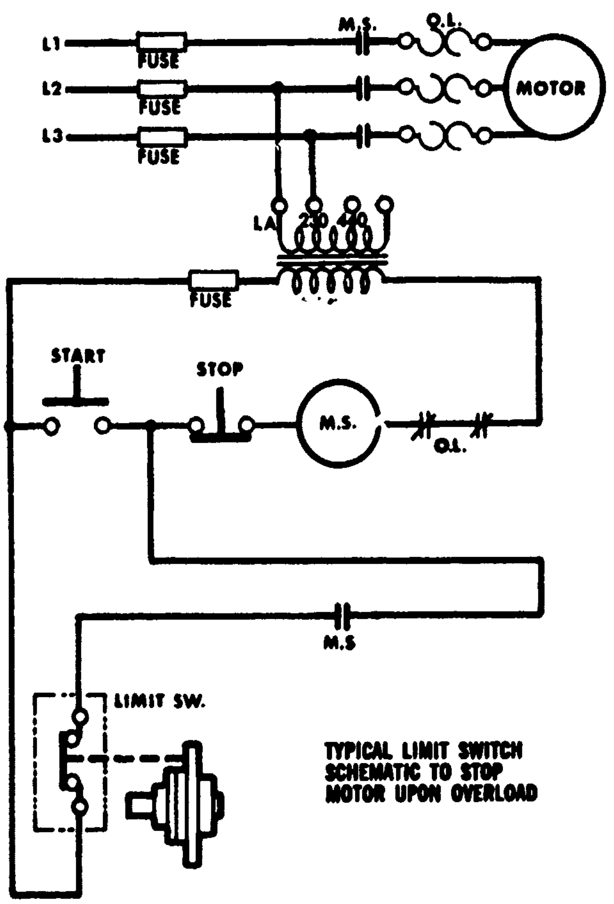
Rotating motion is transmitted by a series of spring loaded hardened steel balls (1) retained in spherical seats between a driving (2) and a driven (3) hub. If load on the machine exceeds set limits for which spring pressure (4) has been established, springs compress (5), allowing the hubs to part sufficiently for the balls to roll over ridges from seat to seat (6), thus terminating the rigid connection between the hubs. Driving hub continues to rotate but the driven hub stops. Balls reseat when load drops to normal and lock the hubs together to resume transmission of power.

An optional single positioning feature (7) insures that balls return only to their original seats so that machine cycle begins at the exact point where disruption occurred. Rite-Torqs with this feature normally have a maximum speed of 100 RPM and require a limit switch (See back page). Consult factory if higher operating speeds are desired.

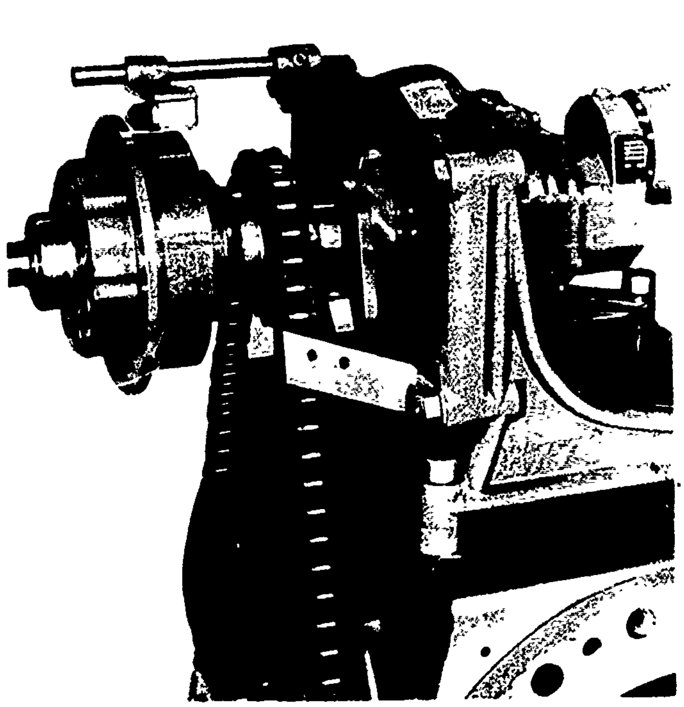
TO STOP MOTOR

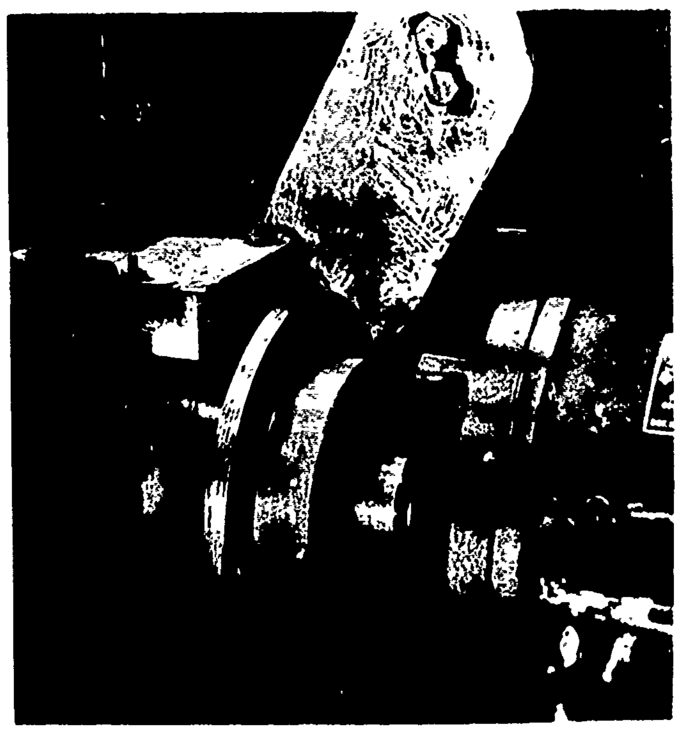
At instant of overload there is an axial displacement ("D" movement in dimensional drawings and table) of the driving hub. It is this movement which creates the clearance between the hubs that allows passage of the balls from seat to seat. The displacement may be employed to actuate a limit switch to stop the power supply. The photo shows a typical installation with a Type C Rite·Torq. A similar arrangement is feasible with the Type S models.

In addition to shutting down the power supply the limit switch can also be employed to actuate a visual or audible system. Such an arrangement is particularly suitable where installations are remotely located and frequently unattended.



TYPICAL LIMIT SWITCH SCHEMATIC TO STOP MOTOR UPON OVERLOAD

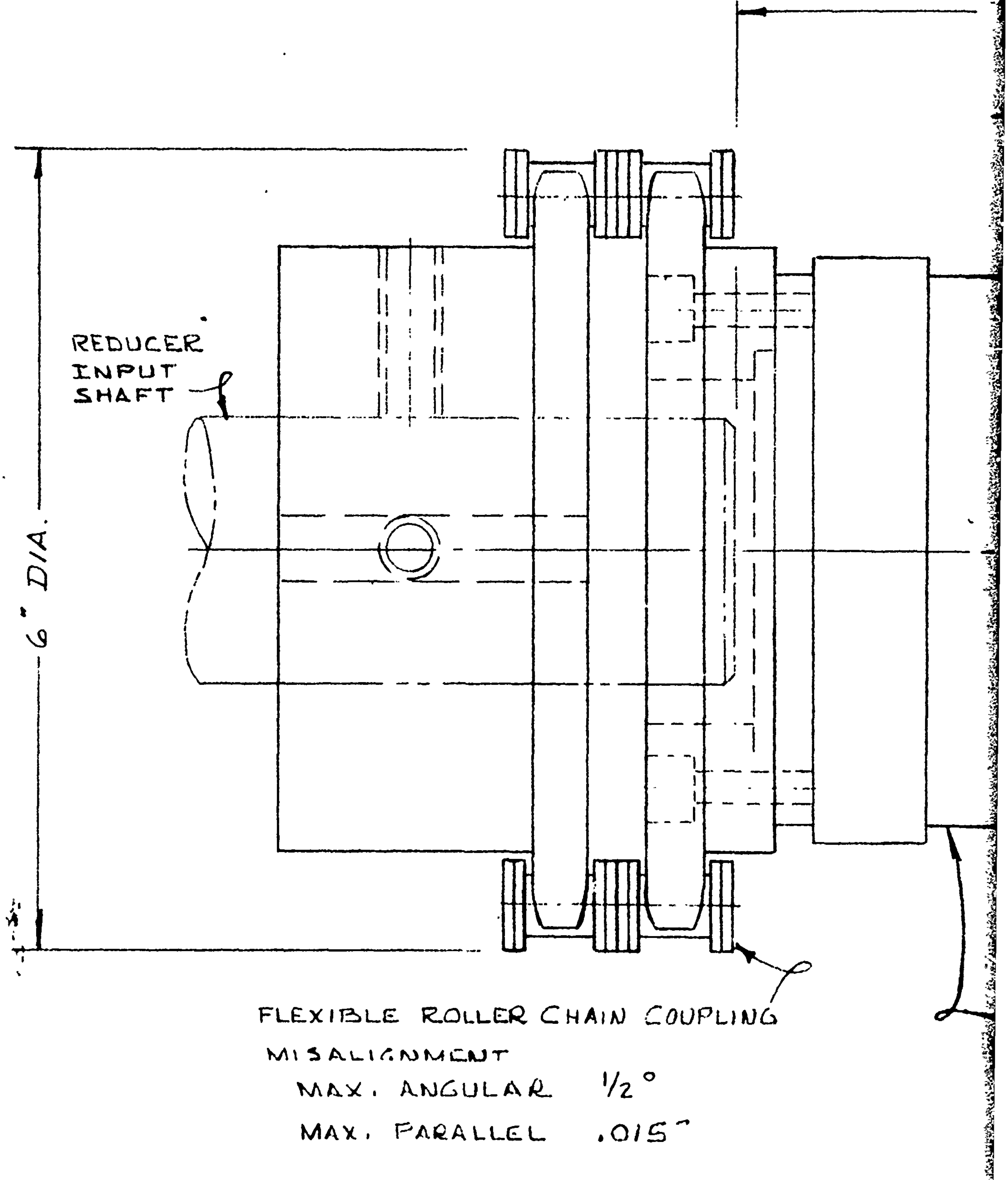




DISTRIBUTED BY:

FERGUSON MACHINE COMPANY

Printed in U.S.A.


REDUCER INPUT SHAFT
6" DIA.
FLEXIBLE ROLLER CHAIN COUPLING
MISALIGNMENT
MAX. ANGULAR 1/2°
MAX. PARALLEL .015"

(1)

(2)

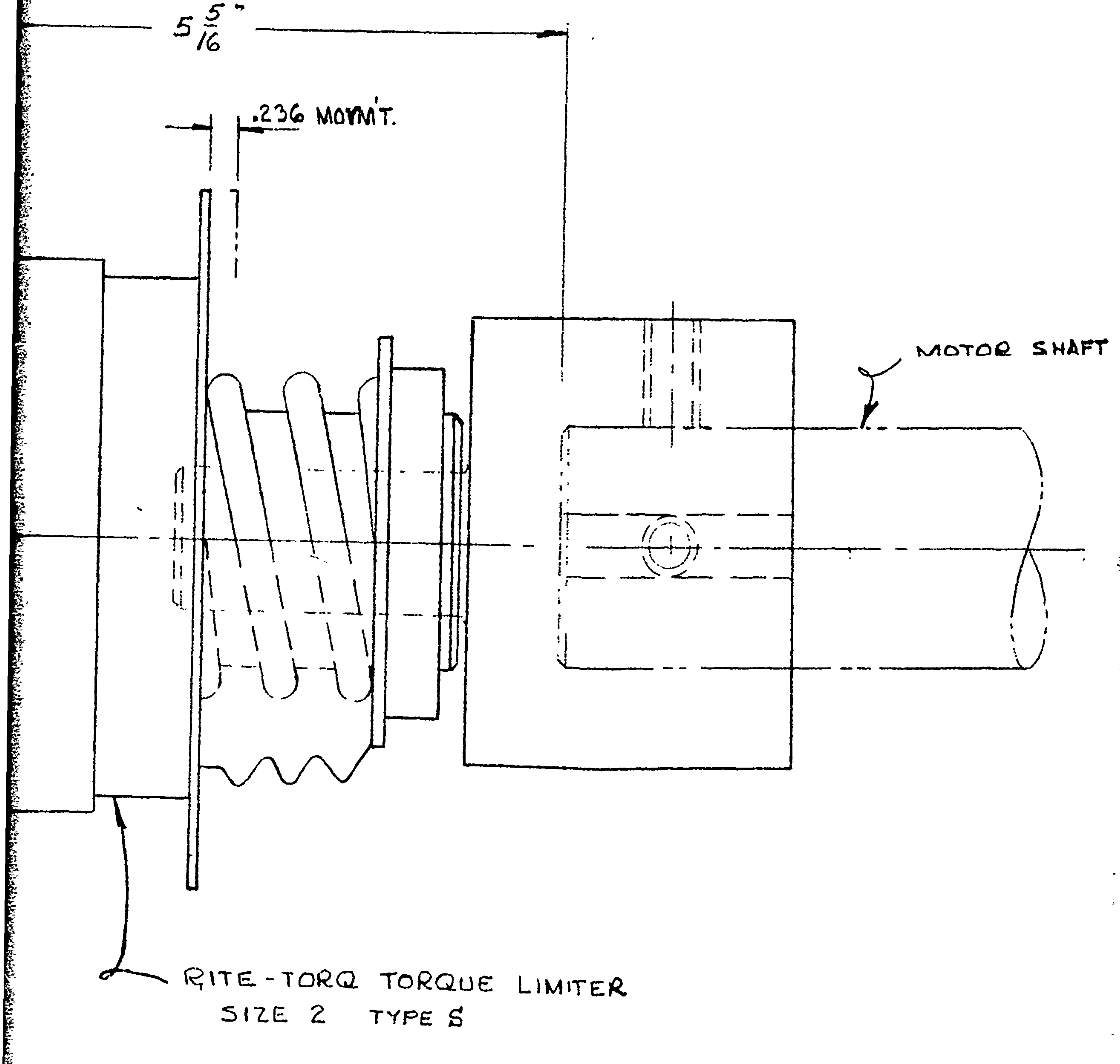
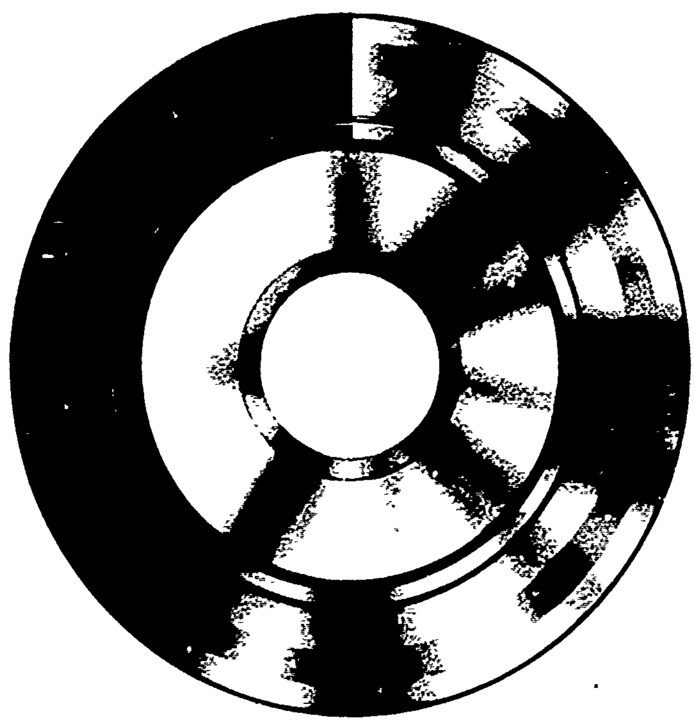

5 5/16"
.236 MOVM'T.
MOTOR SHAFT
RITE-TORQ TORQUE LIMITER
SIZE 2 TYPE S

FIG NO. 9

DAVID BROWN SADI

Mechanical Torque Limiter



Mechanical Torque Limiter

The David Brown Torque Limiter provides dependable protection for driving and driven machinery accurately, tripping whenever the preset torque is exceeded regardless of rotational speed.

No slip drive below tripping torque. Operates at speeds up to 2,000 rpm in either direction and may be mounted in any position.

Design based on standard electric motor shaft extensions allows input hub fitting to electric motors, gearbox shafts and all driving machinery via chains, vee belts and shafts to driven machinery.

Immediate mechanical action gives accurate tripping indefinitely with virtually no maintenance. Overcomes the delay, friction/heat generation, torque variation, maintenance and resetting problems associated with electrical devices, shear pins and slip clutches.

For long starting times (high inertia drives) or where it is desired that the limiter trips very close to the effective running torque of the machine a simple special feature is supplied.

Wear resistant. Tripping components are in heat treated chromium alloy steel and standard torque limiters have been subjected to 50,000 trip cycles at the design torque loading with negligible wear.

Fully enclosed, lubricated for life unit supplied fully bored to suit your driving shaft and with vee belt pulley, chain sprocket or shaft coupling for immediate operation. May be used in machines fully immersed in oil if desired.

The tripping torque may be preset before despatch or adjusted on site with a C. spanner.

Resetting is automatic or supplied with a simple manual resetting accessory.

A wide variety of versions may be made to order for particular applications, for example; single position re-engagement enabling the relative angular position of driving and driven hubs to be maintained; single direction action, tripping limited to 2 revolutions before re-engagement automatically, and minimal backlash.

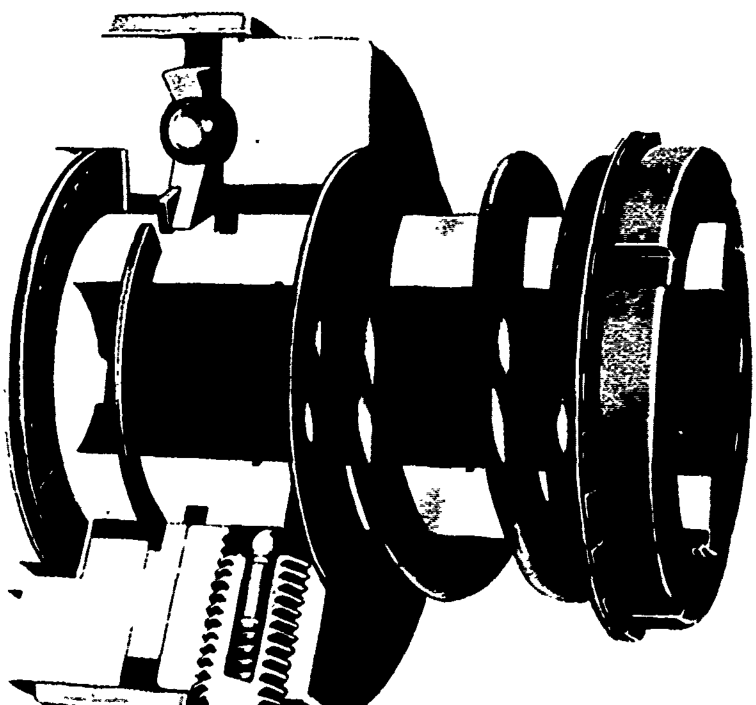
May be used with a limit switch activated on disengagement to cut-off electricity supply to motor.

Every torque limiter is fully tested before despatch, and protected against corrosion in service

The relatively low cost of a David Brown Torque Limiter will be more than recovered in downtime and equipment damage savings the very first time there is an overload.

PROTECTION

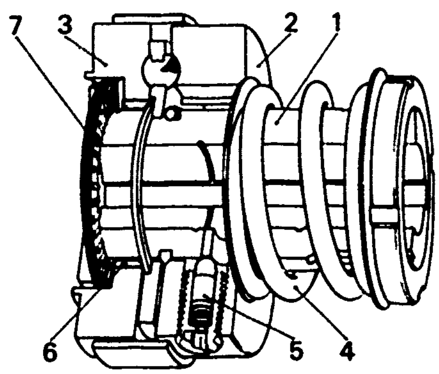
LOW COST!



Patents applied for in U.K., France, Belgium, Spain, Italy, U.S.A., Canada, Germany and Japan.

Selection

The drive is transmitted from the hub (1) to the driving ring (2) and via steel balls to the output ring (3). On overload, when the separating force exceeds the spring pressure (4) the balls move out of their seats displacing the driving ring which will activate the limit switch to cut the motor supply current or activate a warning signal. With the manual reset version the pin (5) prevents the driving ring (2) from returning when the overload is reduced and the hub (1) turns freely on the self lubricated bearing (6) and thrust beari:ıg (7) whilst the ouput ring (3) remains stationary.



The unit is lubricated for life and conforms to DIN P.33 or C.E.I. IP.44 standards of protection. For excessively dusty or adverse atmospheric conditions consult our technical department.

Specify as follows:—

Size	Bore	Speed Range	Type	Torque Setting
2	C	H	W	4 mkg.

Example Specifies:—

A size 2 Sprocket drive with a 24 mm bore suitable for operating speeds of between 500 and 2,000 rpm, and a torque setting of 4 mkg.

For the types M and P add details of the output hub bore and keyway required.

Add special features required, e.g. manual reset, one position reset, non standard sprocket etc. To enable us to check your selection, add details of the type of machine concerned, the motor characteristics and the proposed mounting position.

All units are uniquely identified by the size and serial number stamped on the face of hub (1).

For the majority of applications select the torque limiter with a maximum tripping torque at least equal to 2 × the normal transmitted torque at the point of mounting. The chosen mounting position should be as near to the expected overload as possible.

With motor speed applications inertia forces are involved which vary with the type of motor and methods of starting used. In particular the limiter has to be set such that it does not trip at start or under slow deceleration conditions but that it does trip under stall conditions. For further details consult technical sales sheet No. 370. David Brown trained engineers are available throughout the world to advise on specific applications.

For variable or multi-speed drives:—

Mount the Torque Limiter between driven motor and reduction gear where the same H.P. is required at the different speeds (constant H.P.). Mount the Torque Limiter between the reduction gear output shaft and the driven machine where the H.P. varies in relation to the speed (constant torque).

$$\text{Torque (mkg.)} = \frac{\text{H.P.} \cdot 716}{\text{rpm}}$$

Size	Tripping Torque Mkg. Min. *Also Standard Factory Setting	Max. Speeds between 500-2,000 rpm (H)	Max. Speeds below 500 rpm (L)	Inertia mkg²	Approx. Weight Kg Type T	Standard Bore Sizes mm	Corresponding Standard European Motor at 1,500 rpm HP
A						Pre bore (12)	
B						14	0 33
C	0 3	1 5	4 5	0087	2 3	14	0 5
D						19	0 75
E						19	1 0
A						Pre bore (19)	
B						24	1 5
C						24	2 0
D	1 2	6 0	20 0	0198	3 75	28	3 0
E						28	4 0
F						28	5 5
A						Pre bore (28)	
B						38	7 5
C	5 0	25 0	75 0	0 070	9 0	38	10
D						42	15
E						42	20
A						Pre bore (38)	
B						48	25
C						48	30
D	15 0	50 0	150 0	0 183	14 0	55	35
E						55	40
F						60	50

* *Unless otherwise specified*

It is recommended that the total combined angular and radial misalignment z should not exceed the values shown in the table Where z = x + (y₁ − y₂)

Specification

TORQUE ADJUSTMENT

The release torque is normally factory set at the minimum value. To adjust the setting with the limiter installed in position, the adjusting ring should be screwed progressively clockwise using a C. spanner until the drive operates normally without the limiter tripping. The ring should then be locked in position with the locking ring tab.

Alternatively the torque limiter may be supplied accurately preset dynamically to any desired value.

On request, torque limiters may be supplied with an indicator plate or setting chart allowing the release torque to be set on site to any value within the range with an accuracy of ± 5%.

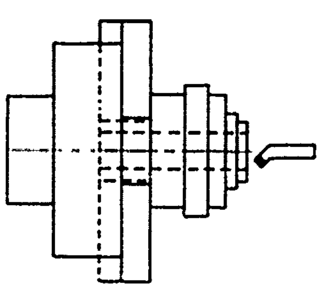
INSTALLATION

The standard torque limiter is supplied complete with the limit switch and

(a) bored and keywayed.

(b) pilot bore. The operations of boring and keywaying can be made without dismantling. *(see illustration below).*

or *(c)* bored and keywayed to client's specifications.



After fitting to the electric motor or machine shaft it is only necessary to restrain the limiter with a screw and washer as shown on the dimension pages.

To reset the manual reset device after tripping, first check that the motor current is switched off. Turn the screw anticlockwise 5 full turns. The limiter will be heard to re-engage distinctly. Finally turn the screw clockwise until fully engaged.

This feature is specified as standard for type 'H' limiters.

For type 'L' limiters expected to trip frequently and for drives with long acceleration times, specify the single position re-setting.

Axial displacement for unit switch on tripping is 5, 6, 7·5, and 10 mm for sizes 1 to 4 respectively.

LIMIT SWITCH

A suggested wiring circuit for the limit switch supplied with the coupling is shown below (see figs., 10, 11 and 12), with the limit switch 9 wired in parallel with the starter 'on' button 14 and in series with the starter "lock in" contact. This will enable the machine operator to start up again after the overload has been relieved, even if the coupling has stopped with the limit switch 'open'. An alarm system or relay (to stop a full line of motors) is possible by use of a 'double throw' limit switch.

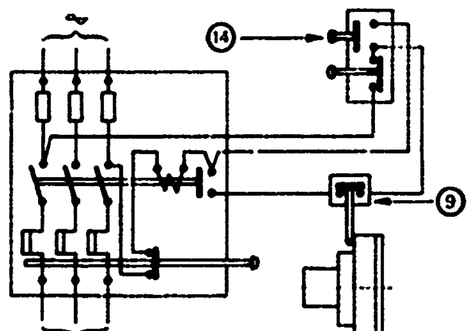


Fig.10

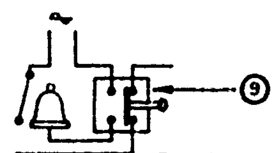


Fig.11

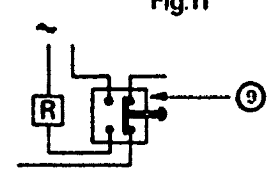
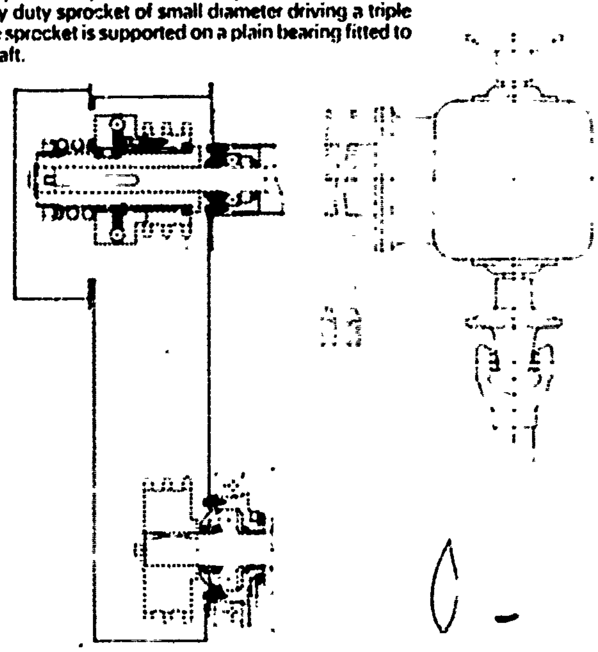
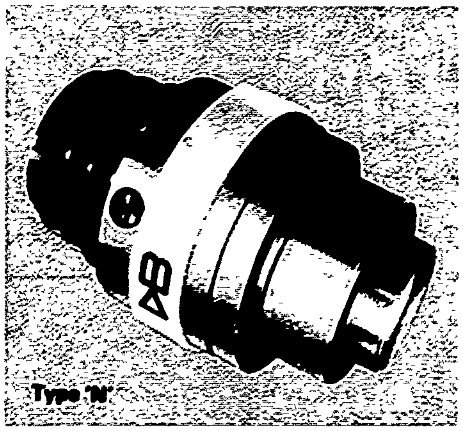


Fig.12

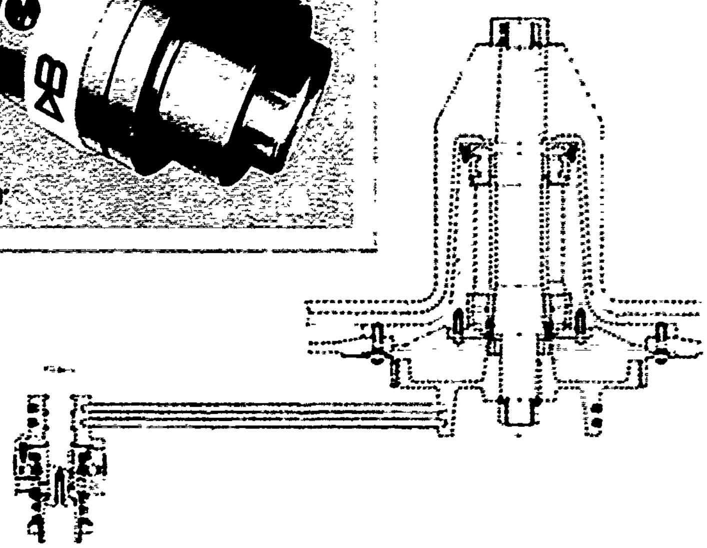
A standard type 'S' torque limiter with special extended hub carrying a heavy duty sprocket of small diameter driving a triple chain drive. The sprocket is supported on a plain bearing fitted to the machine shaft.

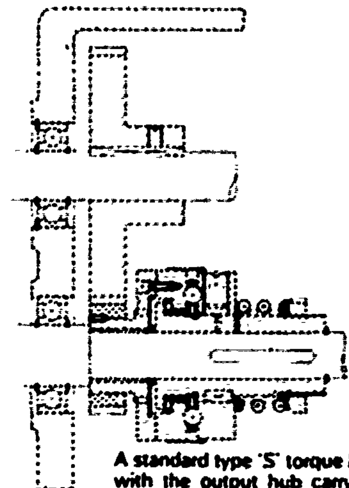


Application examples



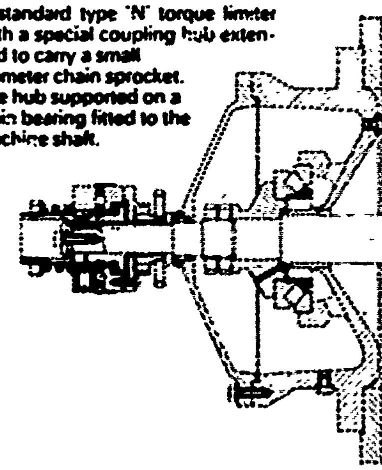
A standard type 'S' torque limiter with special Vee pulley of small diameter driving 2 Vee belts. The pulley is supported on a plain bearing fitted to the machine shaft.



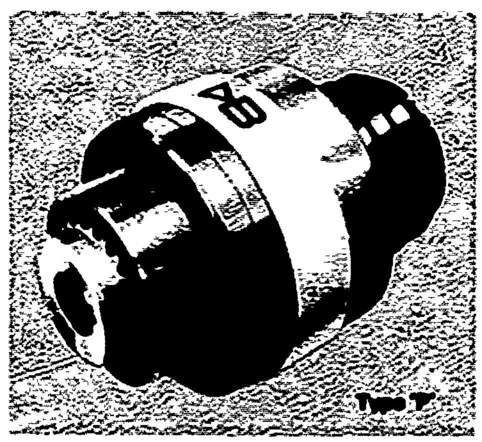


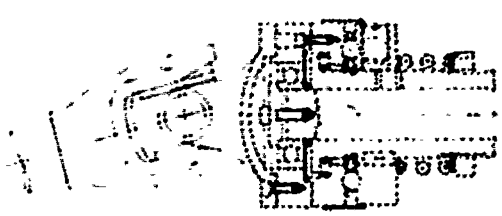
A standard type 'S' torque limiter with the output hub carrying a pinion gear. The hub is machined to accept a plain bearing bush which runs on the machine shaft.

A standard type 'N' torque limiter with a special coupling hub extended to carry a small diameter chain sprocket. The hub supported on a plain bearing fitted to the machine shaft.



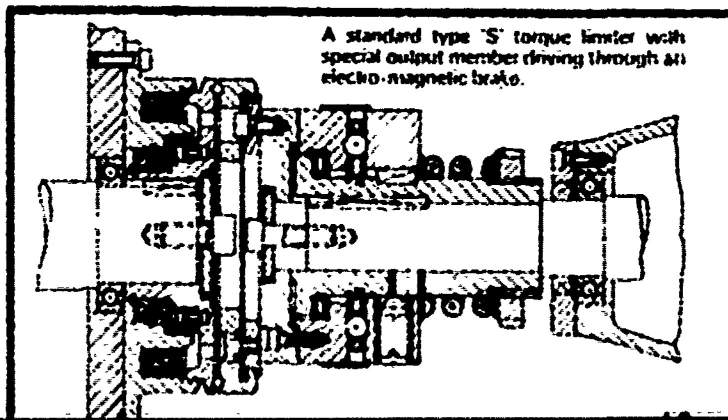
A standard David Brown Torque Limiter motor flange assembly mounted directly onto a standard foot mounting gear reduction unit.





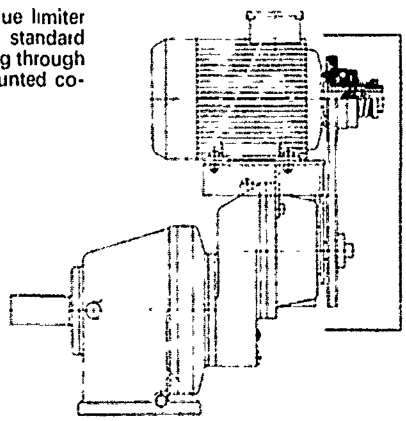
A standard type 'S' torque limiter with special universal joint half coupling supported on a ball bearing fitted to the output shaft of a gear unit.

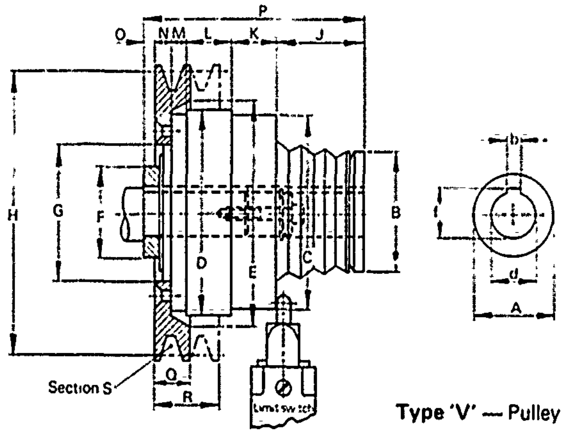
A standard type 'S' torque limiter with special output member driving through an electro-magnetic brake.



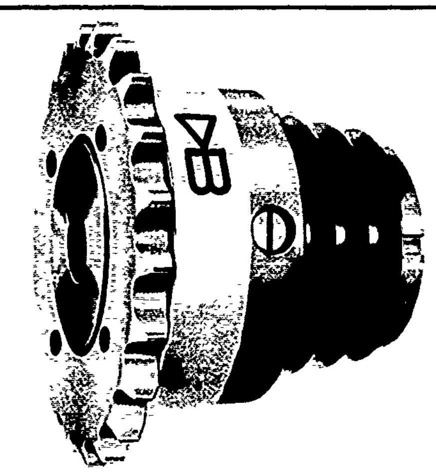
VB Mechanical Torque Limiter

A standard type 'V' torque limiter mounted directly onto a standard electric motor shaft driving through a Vee belt to a foot mounted co-axial gear reducer.

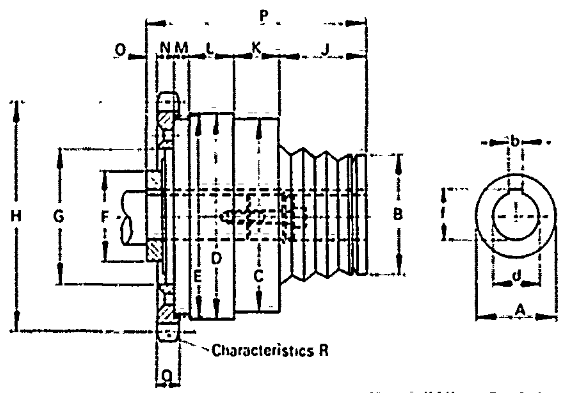




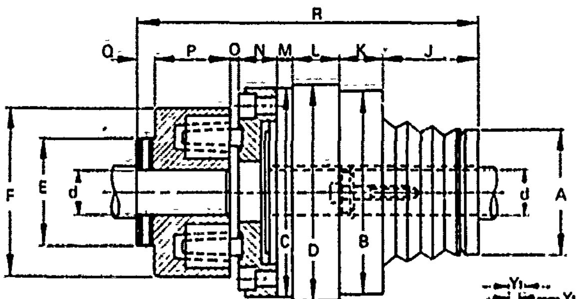
Type 'V' — Pulley Drive

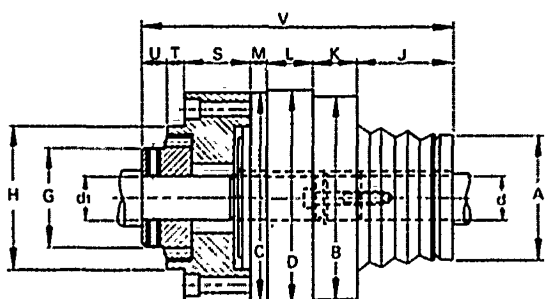


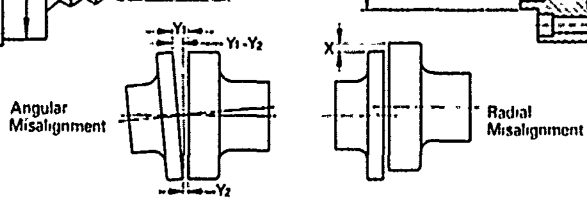
Type 'W'



Type 'W' — Sprocket Drive



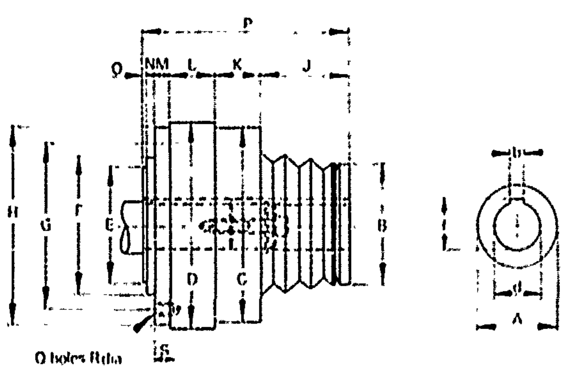




Type 'P' — Shaft Drive

Type 'N' — Shaft Drive

Type 'S'



Type 'S' — Special Applications

Principal dimensions (mm)

Type 'V'

Size	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	b		f
1	35	52	85	90	95	40	60	125	45	18	20	5	7,5	—	95	16	—	SPZ	5 6	14 19	16,3 21,8
2	50	70	103	110	120	40	75	150	56	19,5	23	7,5	8	—	114	20	—	SPA	8 8	24 28	27,3 31,3
3	70	92	133	141	155	60	106	200	83	23	27	10	15	—	158,5	—	43	2× SPB	10 12	38 42	41,3 45,3
4	85	110	160	168	180	70	125	236 250	105	22	40	10	25 33	— —	202,5 210,5	— —	62 82	3× SPB 3× SPC	14 16 16 18	48 55 55 60	51,8 [illegible] 59,3 64,4

Type 'W'

Size	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	b	d	f
1	35	52	85	90	—	40	60	101,3	45	18	20	5	7	6	100	7	25 TEETH SIMPLEX PITCH: ½" DIN 8187	5 6	14 19	16,3 21,8
2	50	70	103	110	108	40	75	133,8	56	19,5	23	7,5	8	6	119	10,5	22 TEETH SIMPLEX PITCH: [illegible]" DIN 8187	8 8	24 28	27,3 31,3
3	70	92	133	141	138	60	106	178,5	83	23	27	10	11	11	164,5	15,3	22 TEETH SIMPLEX PITCH: 1" DIN 8187	10 12	38 42	41,3 45,3
4	85	110	160	168	—	70	125	202,9	105	22	40	10	18	[illegible]	207,5	18	20 TEETH SIMPLEX PITCH: 1¼" DIN 8187	14 16	48 55	51,8 59,3
	85	110	160	168	168	70	125	207,3	105	22	40	10	19	14	210,5	23	17 TEETH SIMPLEX PITCH: 1½" DIN 8187	16 18	55 60	59,3 64,4

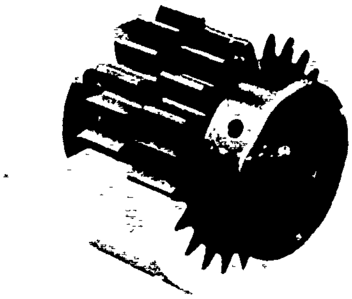
Types 'P' & 'U'

Size	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	d Min.	d Max.	d1 Min.	d1 Max.	Allowable Alignment Errors Z
1	52	85	87	90	45	70	40	58	45	18	20	5	16	2	33	7	146	29	8	10	135	12	19	10	25	0·5
2	70	103	110	110	55	80	40	70	56	19.5	23	7.5	10	2	31	14	169	29	8	10	153	19	28	10	25	0·5
3	92	133	135	141	85	115	58	95	83	23	27	10	22	2	37.5	17.5	272	30	15	12	200	28	42	15	38	0·5
4	110	160	162	168	100	158	78	120	105	22	40	10	30	2	45	51	305	35	20	25	257	38	60	28	55	0·7

Type 'S'

Size	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	b	d	f
1	35	52	85	90	51	60	72	87	45	18	20	5	4	1	93	4	M6	10	5 6	14 19	16.3 21.8
2	50	70	103	110	—	75	90	104	56	19.5	23	7.5	4	—	110	4	M6	10	8 8	24 28	27.3 31.3
3	70	92	133	141	94	106	118	135	83	23	27	10	8	4	155	6	M6	12	10 12	38 42	41.3 45.3
4	85	110	160	168	108	125	140	162	105	22	40	10	8	10	195	6	M8	18	14 16 18	48 55 60	51.8 59.3 64.5

David Brown Shaft Couplings

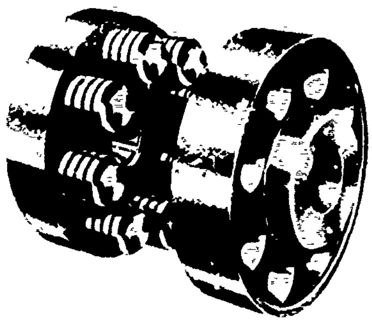


NYLICON

Flexible coupling

Torque: 2,03 to 47,2 mkg
Speeds: up to 9,000 rpm
Bores: 10 to 55 mm

See publication E.304.11

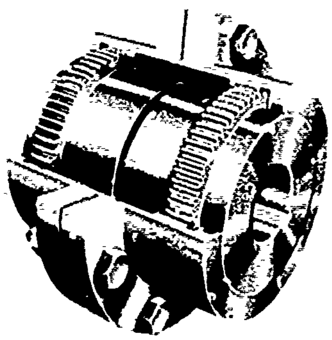


CONE-RING

Flexible and rigid couplings

Torque: up to 19,000 mkg
Speeds: up to 4,420 rpm
Bores: 18 to 355 mm
Flange type or with drum for a brake

See publication E.304.18



GEAR TYPE COUPLING

Torque: 203 to 5,420 mkg
Speeds: up to 6,000 rpm
Bores: 18 to 190 mm
Suitable for heavy duty drives

See publication E.304.24

For further details ask for technical documentation or call and see us.

DAVID BROWN SADI S.A.
Rue des Carburants 4
B-1190 BRUXELLES (Belgium)
Tel.: 02/345 18.01 Telex: 23 199 DBSADI B

THE DAVID BROWN GEAR INDUSTRIES Ltd. Associated companies in U.K., as well as in Australia, Belgium, Canada, France, India, Norway, South Africa, Spain, Switzerland and U.S.A

4.8 Formsprag Reset Clutch, Reference Fig. #10

4.8.1 Formsprag clutch type JCB Model #3, uses the ball detent principle with a multiple spring control torque release setting.

4.8.2 By nesting (2) sets of springs (a set of (20) light and a set of (20) heavy springs), a torque range from 7 Ft. Lb. to 150 Ft. Lb. is applied to (6) 5/16" diameter balls located on the same radius with a specific spacing which allows disengagement for (1) revolution before resetting. The light set of springs when used by themselves, cover a range from 7 to 40 Ft. Lb. The heavy set of springs used separately, have a range of 23 to 120 Ft. Lb. The two sets used together provide a range of 32 to 150 Ft. Lb. torque.

4.8.3 To cover a 3 through 10 HP range, the two sets of springs would be used separately with the light set covering the lower portion of the H.P. range, up through approximately 6 H.P., and the heavy set of springs would use from there onto 10 H.P. maximum.

4.8.4 The construction is all steel except for a plastic plug located under the set screw in nut #4 and the bronze Oilite bushings.

4.8.5 No provision is made for lubrication of the needle bearing and according to the factory none is required for the entire unit.

4.8.6 Other features are,

(a) Bi-directional operation

(b) All position mounting

(c) Fully enclosed

(d) Setting accuracy ± 5%

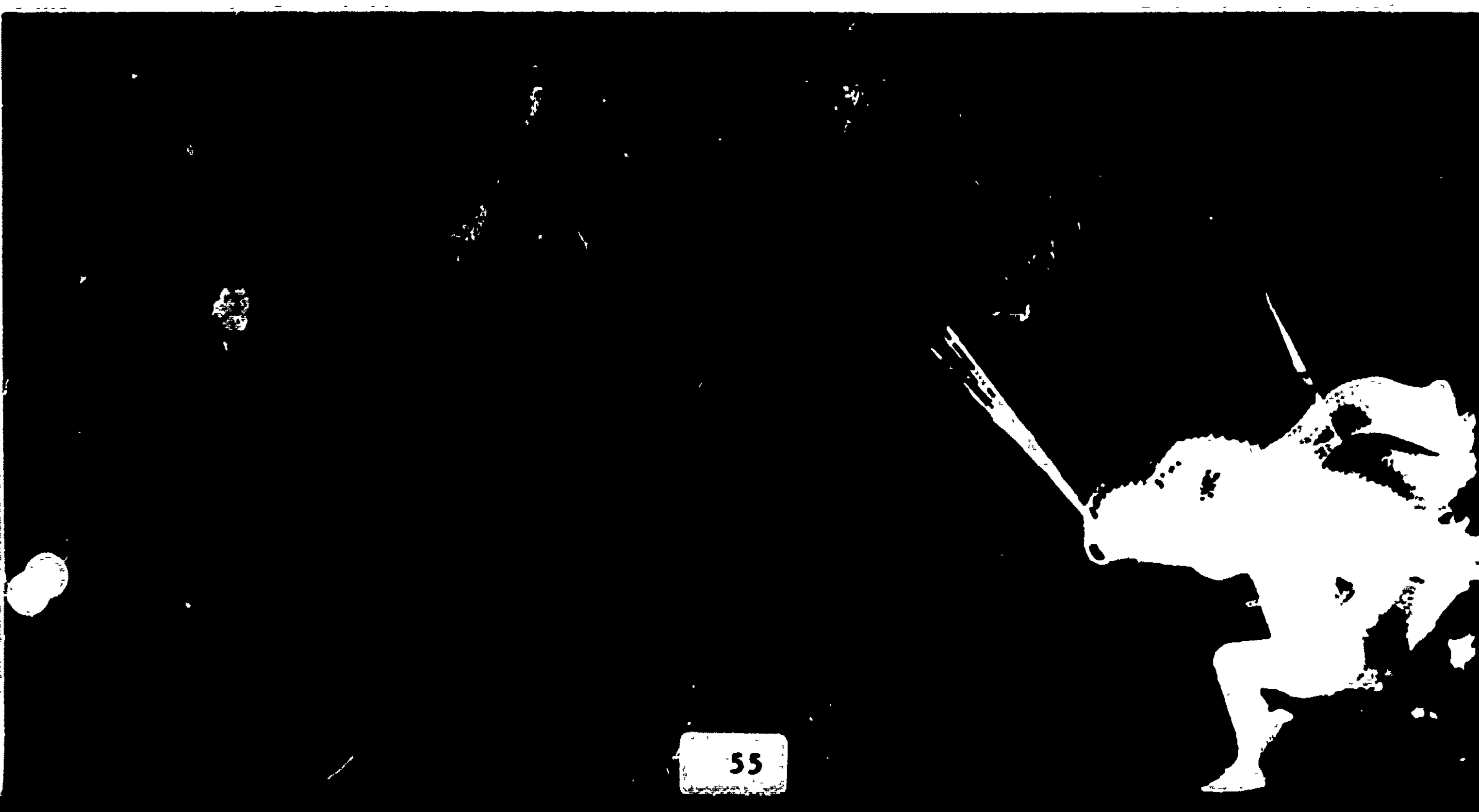
(e) Automatic self-engagement on restart

(f) Automatic cutoff switch operation (with the addition of a tripping plate welded or brazed to the housing)

(g) Externally adjustable with no means other than a set screw for maintaining any preselected setting.

4.8.7 A flexible coupling can be added to the basic clutch, same as the method shown on Figure 9. Due to being somewhat more compact than other designs, only 4" is required for mounting between the motor and reducer shaft. With a 1" maximum standard bore, an adapter is required for one side.

TORQUE LIMITING CLUTCHES



FORMSPRAG

FORM-GARD™

(TLC) TORQUE LIMITING CLUTCHES

- YEARS OF TROUBLE-FREE SERVICE
- VIRTUALLY NO MAINTENANCE
- REMOVE OVERLOAD PROBLEMS
- COMPETITIVE FIRST COST

Gone are the problems associated with slow reaction electrical overloads, shear pins which give a wide torque variation and rapidly overheating slip clutches.

Form-Gard Torque Limiters will save you money. The initial cost normally is more than covered by saving of down time during the first overload.

A complete engineering service is available. Let our Sales Engineers assist you on your particular problems.

NOTICE

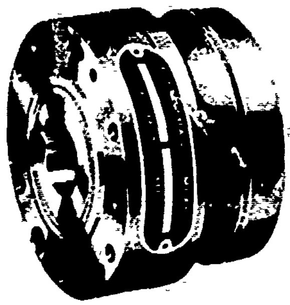
This catalog provides the required guidance. It is the customer's responsibility to apply and install the torque limiting clutch so that it functions within the limits intended by Formsprag. Since proper selection and application is essential to long and satisfactory service, it is important ot give careful attention to the pages which provide information on selection, service, and applications. Any unusual operating conditions requiring selection or application assistance beyond that supplied in the following sections should be referred to the Formsprag Company to assure that the correct size and type of clutch is provided.

FORMSPRAG®
the professionals in motion

Formsprag Company has been marketing and delivering dependable, long-lived, precision-power transmission products for over a quarter century. Formsprag provides one of the broadest lines of industrial brakes, clutches, couplings, sensors and electronic controls in the world. Custom design capability is our specialty.

Formsprag's leadership in motion control results from a conscious, day-after-day striving for product excellence and satisfaction for you, the customer. Our unequalled Engineering, Manufacturing and Marketing team is at your disposal, ready and able to provide you with exactly the right product, exactly when you need it, and competitively priced. Put us to work for you. Formsprag. The company that isn't satisfied until you are.

PTDA

CONTENTS		APPLICATIONS
SECTION **1** Types JAB, JAS, JAP, JAR, JAF. Complete release – manual reset. Pages 5, 6, 7		**MANUAL RESET** **(BASIC TYPE JAB)** mining equipment, conveyors, machine tools, woodworking and paper machinery, pumps, textile machinery, test rigs, rolling mills, quarrying plant, Post Office machinery, extruders, automatic furnaces and ovens.
SECTION **2** Types JCB, JCS, JCP, JCR. Complete release for one revolution – automatic reset. Pages 8, 9, 10		**AUTOMATIC RESET** **(BASIC TYPE JCB)** conveyors, bakery equipment, sliding and folding door actuators, packaging, bottling, labelling machines, printing presses and special-purpose machines.
SECTION **3** Type JFV. Complete release – manual reset. Page 11.		**PTO PROTECTION** **(BASIC TYPE JFV)** Vehicle PTO drives, vane, lobe, screw and centrifugal pumps – vane and lobe blowers.

BEYOND THE CATALOG

MODIFICATIONS & CUSTOM DESIGNS

The wide range of sizes and capacities covered by the Form-Gard Catalog line of clutches will cover most industrial needs; however, your requirements may be better satisfied by other than standard clutches. In many cases standard clutches can be adapted to your special use by a minor modification.

If you require a custom design, Formsprag's quarter of a century experience in the specialized Power Transmission field makes available the depth and expertise required to meet your requirements in the most economical way possible. Please tell us what your requirements are. We will be pleased to quote special designs.

FEATURES	BENEFITS
Automatic and complete disengagement on overload is standard on JA and JF models	No torque is transmitted, thus preventing damage and machine downtime due to overload
Easy to reset because no spring compression or ball alignment is required. Type JC available with automatic reset.	Operator can reset his own machine, avoiding production delays
A single Form-Gard Type-JA Clutch will function as: (1) "Dog Clutch" (2) Overload Release Clutch	Eliminate the need for two seperate clutches Reduce system cost, complexity and size
All metal totally enclosed construction	Longer life in contaminated environment Operator safety improved with enclosed springs
Drive torque is transmitted thru tapered jaws on all standard type JA models	Positive drive — no slip or backlash Timing of drive system is assured.
Torque setting accurate within ± 5% is maintained indefinitely	Accurate Ease of maintenance is assured by eliminating the need for continuous adjustment
Bi-directional torque transmission is standard	Selection of proper clutch is simplified Standard unit can be installed on dual direction drive system
Reduced overall length	Reduce the space required and the cost of your drive system
Multiple springs control torque release setting	Increased dependability of drive Larger range of torque setting is available to meet your specific application

OPTIONAL FEATURES

SINGLE POSITION RE-ENGAGEMENT
For use where timing of machine is required. Available for Types JA and JC.

LIGHT DUTY SPRINGS
For systems requiring very low torque levels and greater range of adjustment sensitivity.

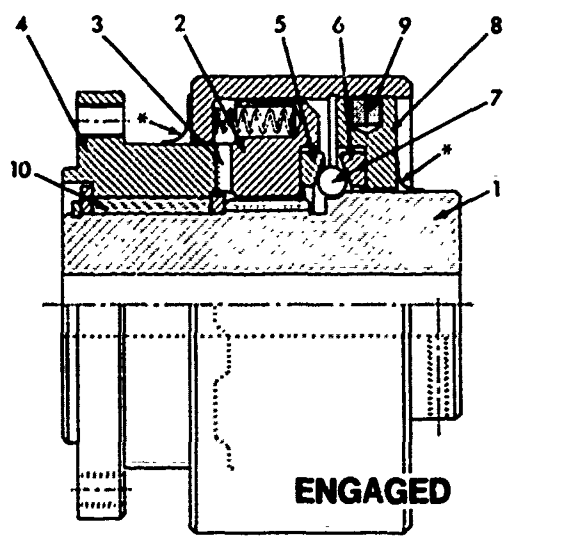
SINGLE DIRECTION OVERLOAD RELEASE
For applications where heavy braking is applied. Type JA only.

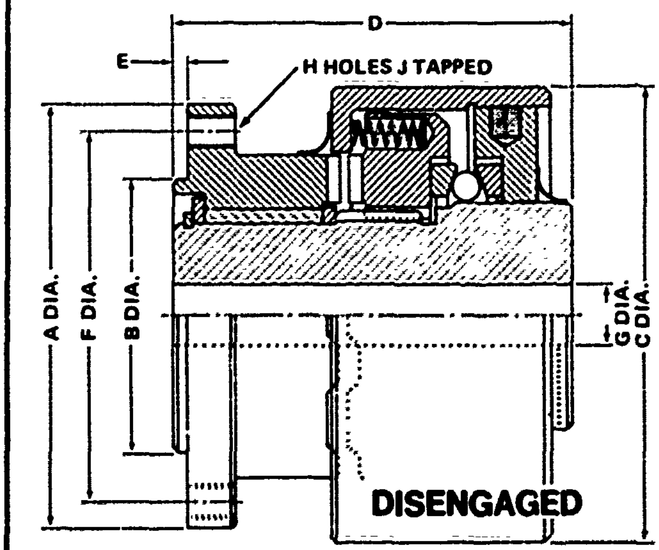
DUAL LEVEL TORQUE SETTING
For heavy overrunning applications which require normal release torque setting in one direction and a lower torque release setting in the opposite direction. Type JA only.

BASIC MANUAL RESET CLUTCH — TYPE JAB

TECHNICAL FEATURES

**Complete disengagement on overload ● Simple "one screw" torque adjustment ● Positive drive – no slip
Rapid easy reset ● Full bi-directional operation ● Horizontal or Vertical Mounting ● Torque setting maintained indefinitely
All metal totally enclosed construction ● Release action can operate a warning device or limit switch
Rugged and compact design ● May also be used as a lever operated clutch**





JAB MODEL	RELEASE TORQUE Min. (Note 1) lb ft / kgm	Max. lb ft / kgm	Max. HP/RPM	A	B (Note 2)	C	D	E	F	G max.	G min. (Note 3)	H	J unc	Axial movement on overload (Note 3)	WEIGHT lbs / kg
2	10 1.4	100 14	.02	3.54 90	2.16 55	3.75 95	3.35 85	0.118 3	2.95 75	1.00 25.4	0.50 12.7	6	¼-20	0.25 6.35	6.5 2.95
5	50 7	500 70	.1	4.70 120	3.15 80	4.92 125	3.54 90	0.118 3	3.94 100	1.57 40	0.75 19.05	6	⅜-16	0.25 6.35	12.3 5.50
7	350 49	1000 140	.2	7.09 180	4.33 110	7.09 180	5.91 150	0.118 3	5.91 150	2.24 57	1.25 31.75	6	½-13	0.25 6.35	37 17
8	450 63	2000 280	.4	9.25 235	5.91 150	9.06 230	5.91 150	0.118 3	7.68 195	3.03 77	1.50 38.1	6	⅝-11	0.25 6.35	66 30
9	600 84	4000 560	.8	12 305	7.874 200	12 305	8.07 205	0.118 3	10.63 270	4.00 102	2.00 50.8	6	¾-10	0.32 8.13	165 84

Note 1: Lower release torques can be achieved – Consult Formsprag Company.
Note 2: Tolerance on pilot diameter – Consult Formsprag Company.
Note 3: Dimensions "G min." and "Axial movement on overload" also apply to Types JAR, JAF, JAS and JAP.

Normal running

The drive is transmitted from the hub (1) through the splined ring (2) via the tapered jaws (3) to the coupling flange (4). The jaws are normally held together by spring pressure acting through two angled races (5 and 6) and a full complement of balls (7) located by a step on the hub.

Disengagement

On overload, the tapered jaws are thrust apart, moving the splined ring (2) and lifting the balls (7) over the step on the hub, thus completely disengaging the drive, leaving flange jaw ring (4) free to rotate on bearing (10).

Torque adjustment

The release torque settings are made by adjusting the control ring (8) so altering the spring forces. The adjusting ring is locked in position by a nylon plug (9) or, if preferred, a set screw.

Installation

Clutches can be supplied rough bored or finish bored and keywayed. The hub may be fitted to either shaft and the flange can be connected to a flexible coupling or can carry a sprocket or pulley. See pages 6 & 7.

Re-engagement

To re-engage, the tapered jaws are aligned using reference marks and the sliding assembly is pushed along the hub until the balls snap back into their original position. This requires no further spring compression.

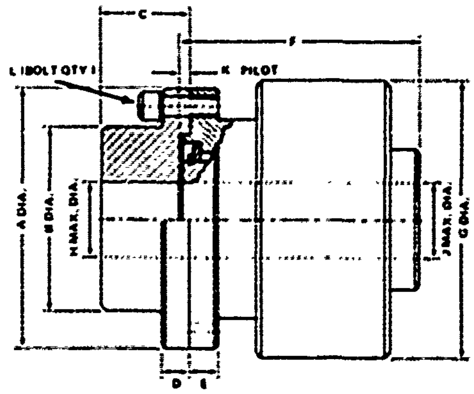
Application

The clutch can be installed in any drive system, safeguarding against sudden surges or gradual build-up of torque. Modifications are possible to provide manual lever operation of the clutch while retaining the overload release feature. Single direction release and one position mesh can also be provided. (For speeds above 1750 RPM consult Formsprag.)

Note:
For particularly dusty conditions such as cement works we offer neoprene seals at positions (*) above. Please specify when ordering.

TYPE JAR

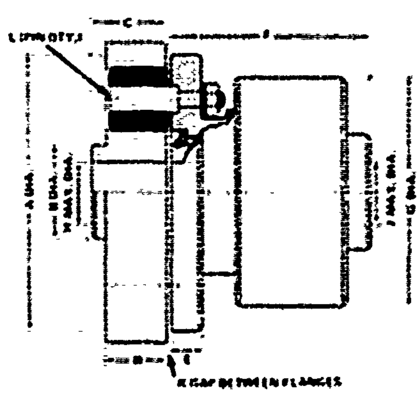
TYPE JAB WITH RIGID COUPLING



JAR MODEL	RELEASE TORQUE Min. lb ft / kgm	RELEASE TORQUE Max. lb ft / kgm	Max. HP/RPM	A	B	C	D	E	F	G	H	J	K	L	WEIGHT lbs / kg
2	10 / 1.4	100 / 14	.02	3.54 / 90	2.56 / 65	1.57 / 40	0.59 / 15	0.39 / 10	3.35 / 85	3.74 / 95	1.57 / 40	1.00 / 25.4	0.118 / 3	6	12.5 / 5.7
5	50 / 7	500 / 70	.1	4.72 / 120	3.35 / 85	1.61 / 41.28	.625 / 15.9	0.51 / 13	3.54 / 90	4.92 / 125	1.97 / 50	1.57 / 40	0.118 / 3	5	22 / 10
7	350 / 49	1000 / 140	.2	7.09 / 180	4.92 / 125	2.62 / 66.7	0.98 / 25.4	0.87 / 22	5.91 / 150	7.09 / 180	3.35 / 85	2.24 / 57	0.118 / 3	6	54 / 25
8	450 / 63	2000 / 280	.4	9.25 / 235	6.50 / 165	3.74 / 95	1.00 / 25.4	0.87 / 22	5.91 / 150	9.06 / 230	4.33 / 110	3.03 / 77	0.118 / 3	6	108 / 49
9	600 / 84	4000 / 560	.8	12 / 305	8.46 / 215	4.65 / 118	1.18 / 30	0.98 / 25	8.07 / 205	12 / 305	5.51 / 140	4.00 / 102	0.118 / 3	6	275 / 125

TYPE JAF

TYPE JAB WITH FLEXIBLE PIN COUPLING



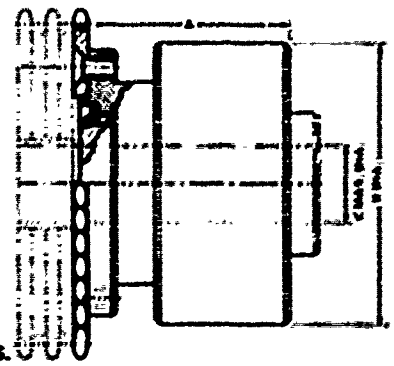
NOTE: THESE PIN COUPLINGS ARE NOT RECOMMENDED FOR HEAVY LOADING

JAF MODEL	RELEASE TORQUE Min. lb ft / kgm	RELEASE TORQUE Max. lb ft / kgm	Max. HP/RPM	A	B	C	D	E	F	G	H max.	H min.	J	K	L	WEIGHT lbs / kg
2	10 / 1.4	100 / 14	.02	6.56 / 166.6	2.95 / 75	1.77 / 45	0.87 / 22.2	0.59 / 15	3.35 / 85	3.75 / 95	1.77 / 45	0 / 0	1.00 / 25.4	0.197 / 5	4	14.97 / 6.8
5	50 / 7	500 / 70	.1	9.125 / 231.8	4.72 / 120	2.56 / 65	2.06 / 52.4	0.98 / 25	3.94 / 100	4.92 / 125	2.95 / 75	0.75 / 19	1.57 / 40	0.197 / 5	6	53 / 24
7	350 / 49	1000 / 140	.2	9.125 / 231.8	4.72 / 120	2.56 / 65	2.06 / 52.4	0.98 / 25	5.91 / 150	7.09 / 180	2.95 / 75	0.75 / 19	2.24 / 57	0.197 / 5	8	76.35 / 34.7
8	450 / 63	2000 / 280	.4	11.25 / 285.8	5.51 / 140	3.35 / 85	2.50 / 63.5	1.18 / 30	6.30 / 160	9.06 / 230	3.15 / 80	1.25 / 31.75	3.03 / 77	0.197 / 5	10	128.61 / 58.46
9	600 / 84	4000 / 560	.8	14.75 / 374.6	8.75 / 222.25	4.75 / 120.65	2.81 / 71.37	1.56 / 39.62	8.07 / 205	12 / 305	4.75 / 120.65	2.50 / 63.5	4.00 / 102	0.25 / 6.35	12	319 / 145

MAXIMUM ANGULAR MISALIGNMENT ± ½ DEGREE

TYPE JAB WITH SPROCKET

TYPE JAS



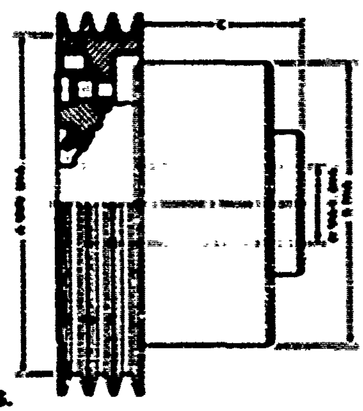
MULTIPLE SPROCKETS WILL USUALLY BE SUPPLIED WITH BEARINGS TO RUN ON CUSTOMER'S SHAFT FOR ADDITIONAL SUPPORT

FOR SPROCKETS SMALLER THAN LISTED AN ADAPTER IS USED – CONSULT FORMSPRAG.

JAS MODEL	RELEASE TORQUE Min. lb ft / kg-m	Max. lb ft / kg-m	Max. HP/RPM	DIMENSIONS IN INCHES AND MILLIMETERS A	B	C	SMALLEST STANDARD SPROCKET (Number of teeth) 3/8" Pitch	1/2" Pitch	5/8" Pitch	3/4" Pitch	1" Pitch
2	10 / 1.4	100 / 14	.007	3.32 / 84	3.75 / 95	1.00 / 25.4	30	26	21	18	15
5	50 / 7	500 / 70	.1	3.43 / 87	4.92 / 125	1.57 / 40	57	32	27	22	18
7	350 / 49	1200 / 168	.2	5.79 / 147	7.00 / 178	2.36 / 60		40	30	30	26
8	450 / 63	2000 / 280	.4	5.79 / 147	9.06 / 230	2.83 / 72			50	37	30
9	600 / 84	4000 / 560	.8	7.96 / 202	12 / 305	4.00 / 102				37	37

TYPE JAB WITH PULLEY

TYPE JAP



NOTE: PULLEYS TO SUIT THE FOLLOWING BELTS CAN ALSO BE SUPPLIED:
- STANDARD "V" SECTIONS
- FLAT
- POLY "V"
- TIMING

FOR PULLEYS SMALLER THAN LISTED AN ADAPTER IS USED – CONSULT FORMSPRAG.

JAP MODEL	RELEASE TORQUE Min. lb ft / kg-m	Max. lb ft / kg-m	Max. HP/RPM	DIMENSIONS IN INCHES AND MILLIMETERS A	B	C	D
2	10 / 1.4	100 / 14	.007	4.53 / 115	3.75 / 95	TO SUIT CUSTOMER'S [illegible] REQUIREMENTS	1.00 / 25.4
5	50 / 7	500 / 70	.1	6.10 / 155	4.92 / 125		1.57 / 40
7	350 / 49	1200 / 168	.2	8.27 / 210	7.00 / 178		2.36 / 60
8	450 / 63	2000 / 280	.4	10.43 / 265	9.06 / 230		2.83 / 72

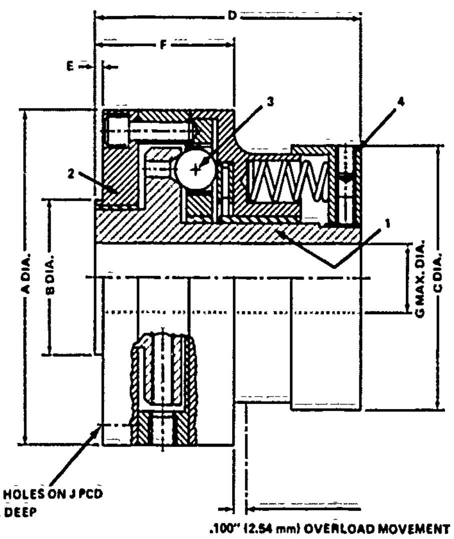
SECTION 2

TYPE JCB

BASIC AUTOMATIC RESET CLUTCH

TECHNICAL FEATURES

Instant release at pre-set torque ● Smooth and complete disengagement for one revolution
Bi-directional ● Horizontal or Vertical mounting ● All metal, totally enclosed
Automatic self-engagement on restart without loss of phasing



JCB MODEL	MAX. RELEASE TORQUE		DIMENSIONS IN INCHES AND MILLIMETERS										WEIGHT lbs kg
	lb ft kgm	HP/RPM	A	B	C	D	E	F	G	H QTY/UNC	J	K	
1	30 4	.006	2.98 76	1.38 35	2.37 60	2.42 62	0 06 1.5	1.23 31	0.63 16	(3) ¼-20	2.60 66	0.31 8	3 1.36
3	150 21	.03	3.70 94	2.13 54	3.44 87	2.56 66	0.06 1.5	1.33 34	1.13 28	(6) ¼-20	3 31 84	0.44 11	6.20 2 80

Normal running

The drive is transmitted between the hub flange (1) and the housing (2) by the balls (3), spring-loaded into the pockets on the hub flange face.

Disengagement

On overload, the balls are displaced axially, further compressing the springs. Once out of their pockets, the balls roll between the face of the hub flange and the needle thrust bearing for one revolution before re-engaging and synchronizing the drive.

Torque adjustment

The release torque is set by a tightening nut (4) thus increasing the spring pressure. After setting, the nut is locked with a set screw and plug.

Installation

Clutches can be supplied rough bored or finish bored and keywayed. The hub may be fitted to either shaft and should be located against a shoulder to resist the resetting spring force. (Fig. 1). The drive flange may be replaced by a sprocket, pulley, etc., or connected to a coupling as shown on pages 9 and 10.

Application

This type of protection is ideally suited to drive systems where it is essential to restart in the correct sequence and where access for manual resetting is not available.

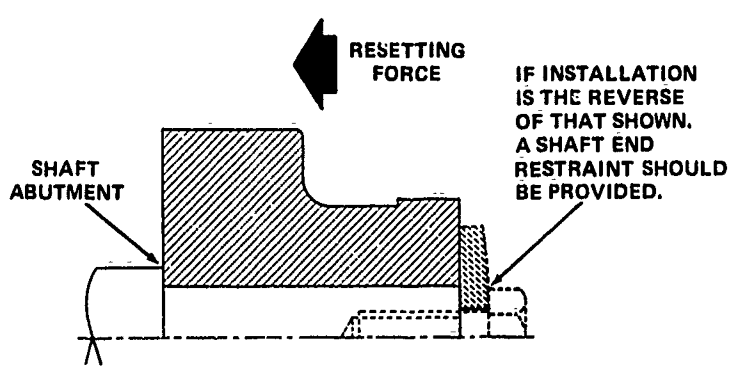


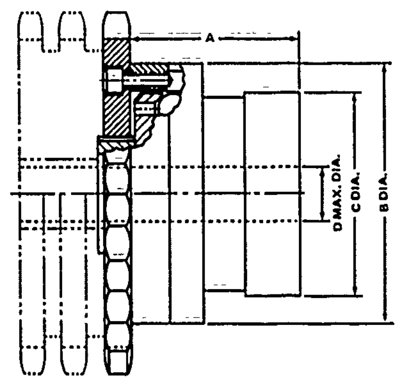
Fig. 1

Note:
Type JC clutches should always be used with a limit switch to bring the drive to rest within a few revolutions thus preventing possible damage by continual releasing and resetting. See Page 12.

TYPE JCB WITH SPROCKET

TYPE JCS

Multiple sprockets will usually be supplied bushed to run on customers shaft for additional support.



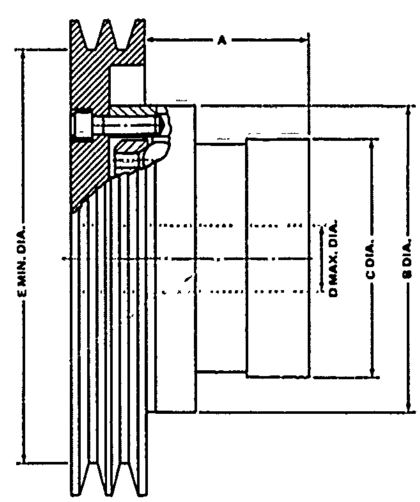
For sprockets smaller than listed, an adaptor is used Details on request.

JCS MODEL	MAX. RELEASE TORQUE		DIMENSIONS IN INCHES AND MILLIMETERS				SMALLEST STANDARD SPROCKET (Number of teeth)				
	lb ft kgm	HP/RPM	A	B	C	D	⅜" Pitch	½" Pitch	⅝" Pitch	¾" Pitch	1" Pitch
1	30 4	.006	2.04 52	2.98 76	2.37 60	0.625 16	30	22	19	17	14
3	150 21	.03	2.10 53	3.70 94	3.44 87	1.125 28	38	28	23	20	15

TYPE JCB WITH PULLEY

TYPE JCP

Note: Pulleys to suit the following belts can also be supplied — standard 'V' section, flat, poly 'V' and timing.

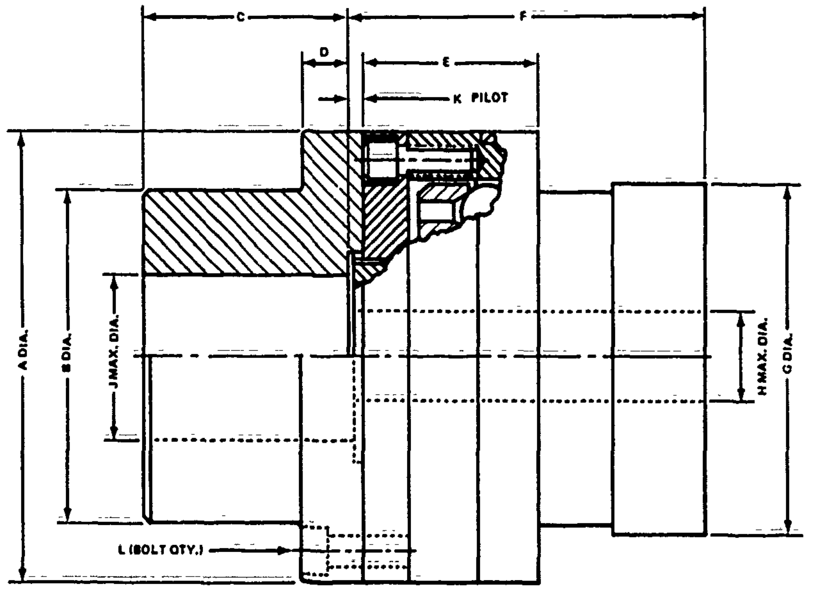


For pulleys smaller than listed, an adaptor is used Details on request.

JCP MODEL	MAX. RELEASE TORQUE		DIMENSIONS IN INCHES AND MILLIMETERS				
	lb ft kgm	HP/RPM	A	B	C	D	E
1	30 4	.006	To suit	2.98 76	2.37 60	0.625 16	4.00 102
3	150 21	.03	To suit	3.70 94	3.44 87	1.125 28	4.875 124

TYPE JCR

TYPE JCB WITH RIGID COUPLING



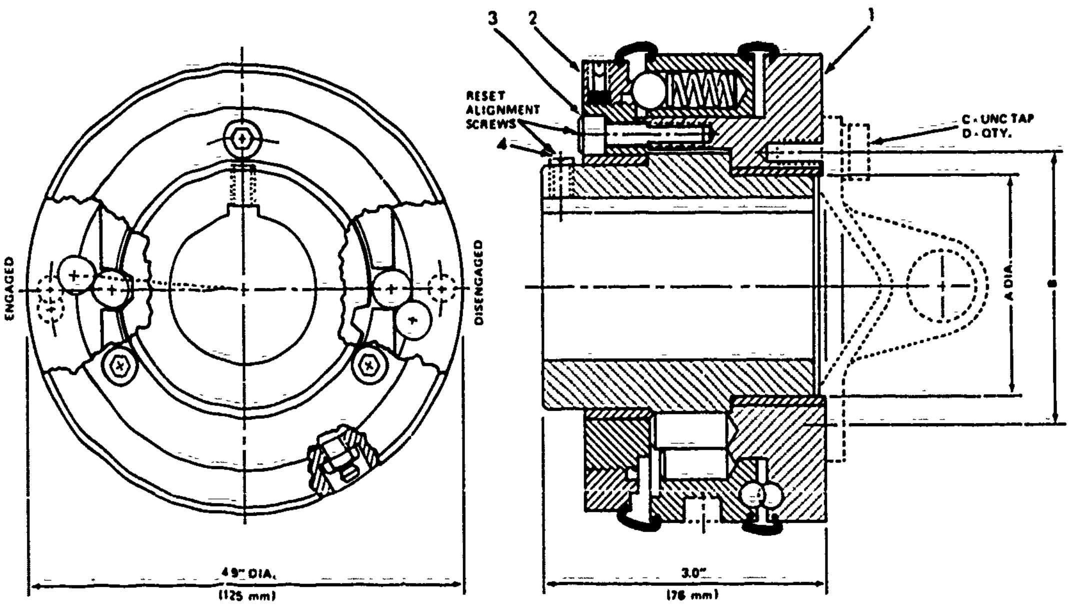
JCR MODEL	RELEASE TORQUE		DIMENSIONS IN INCHES AND MILLIMETERS											WEIGHT
	lb ft kgm	HP/RPM	A	B	C	D	E	F	G	H	J	K	L	lbs kg
1	30 4	.006	2.99 76	2.17 55	1.50 40	0.59 15	1.22 31	2.44 62	2.36 60	0 63 16	1.38 35	0.06 1.5	3	4.5 2
3	150 21	.03	3.70 94	2.79 7	2.00 50.8	0.59 15	1.34 34	2.60 66	3.43 87	1.10 28	1.73 44	0.06 1.5	6	9.5 4.3

NOTE: This arrangement will not accommodate any misalignment.

TYPE JFV

TECHNICAL FEATURES

**Prevents expensive transmission damage by automatically disengaging on overload ● Simple adjustment ● Easy reset
Flange mates with standard series universal joints ● Grease-lubricated ● Maximum speed 2000 r.p.m.
Release torque adjustable up to 360 lbs ft maximum ● Fully sealed against the environment of a PTO drive**



MAXIMUM BORE 1.5" (38 mm) DIA.*
WEIGHT 10.5 lbs. (4.73 kg)

UNIVERSAL JOINT SERIES	PILOT DIA. A	BOLT CIRCLE DIA. B	UNC THD. HOLE C	NUMBER OF HOLES D
1110 or 1140	2.250/2.252	2.750	5/16	4
1300 or 1310	2.375/2.377	3.125	3/8	4
1350 or 1410	2.750/2.752	3.750	7/16	4

Dimensions in inches

INSTALLATION

The hub is mounted on the drive shaft of the PTO using a clearance fit and key. When installing, do not hammer the flange face (1). Mount universal joint to flange using socket head screws.

Release torque setting

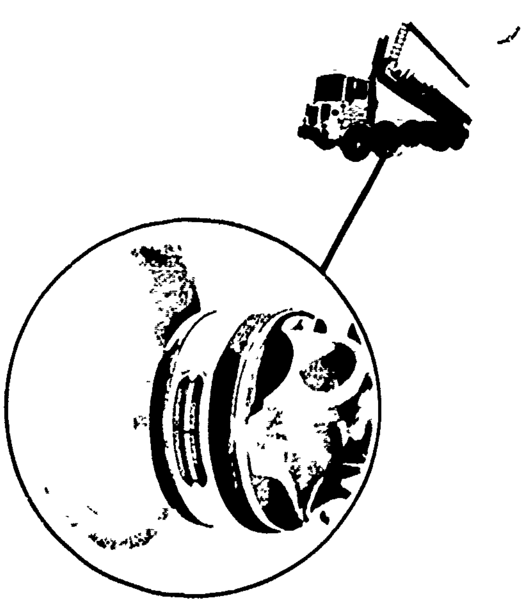
The clutch can be supplied set to your specified torque. To increase the setting, turn the adjusting nut (2) clockwise; to decrease, counterclockwise. Do not unscrew beyond the flush position where the zero marks coincide.

To reset

When the clutch operates and disengages the drive, first locate and clear the cause of the overload. To reset, rotate the flange (1) to align the raised screw (3) in the housing with the set screw (4) in the hub. Hold the flange and, with a pry-bar, turn slightly in the direction of the arrow.

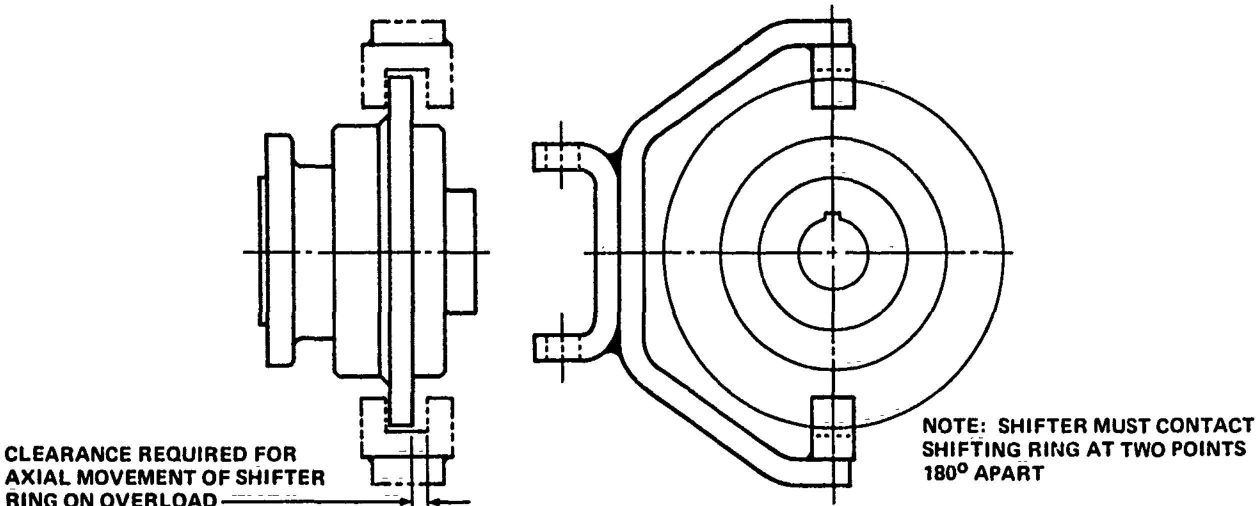
Maintenance

Clutches are grease-packed on assembly with a molybdenum disulphide base of grease. A grease fitting is provided for routine maintenance.



DOG CLUTCH FEATURE

Typical arrangement of Type "JA" with Shifter Ring for use as remote control "Dog Clutch".



A feature of the Type "JA" Clutch is that it can be used as a lever operated "Dog Clutch". By adding a shifter ring to the clutch a conventional yoke mechanism can be used to provide remote control lever actuation to engage and disengage the clutch.

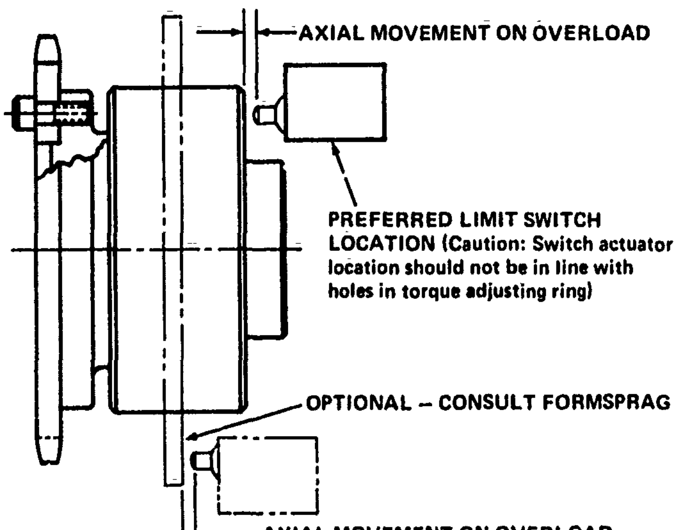
This feature has been found very useful on conveyors for maintenance work which requires disconnection of the gearbox and motor. The Dog Clutch feature can also be used on large machines such as printing presses to disconnect and isolate specific sections.

The normal overload release feature is retained and the dual purpose clutch forms a compact unit with unique characteristics.

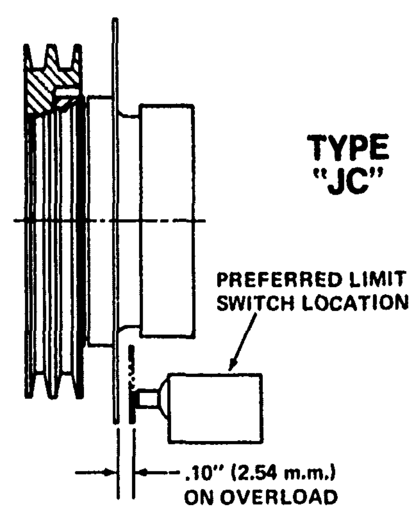
LIMIT SWITCH OPERATION

Typical arrangement of Type "JA" and Type "JC" for use with limit switch for automatic shut-off.

TYPE "JA"



TYPE "JC"



The axial movement of the clutch body on overload can be used to operate a limit switch to shut the drive down or to provide visual or audible warning. Because the Type "JA" clutch is completely free running on overload the use of a limit switch is optional. However, we strongly recommend that a limit switch be used with the automatic Reset Type "JC" clutch unless the operating speeds are very slow.

TYPICAL APPLICATIONS

- BOTTLING EQUIPMENT
- AUTOMATIC FURNACES OR OVENS
- AUTOMATIC DOOR OPENERS
- DRYING DRUMS
- TRANSFER MACHINES
- WASHING MACHINES
- RUBBER PROCESSING MACHINES
- FILM PACKAGING MACHINES
- TOBACCO PROCESSING EQUIPMENT
- SPECIAL MACHINERY
- TRACTOR PTO DRIVEN WINCH
- PACKAGING AND LABELLING MACHINERY
- CONVEYORS
- MACHINE TOOLS
- BAKERY EQUIPMENT
- WOODWORKING MACHINERY
- PRINTING PRESSES
- PAPER MACHINERY
- TEXTILE MACHINERY
- ROLLING MILLS
- PTO DRIVES
- MIXERS
- PUMP DRIVES
- MINING EQUIPMENT

WHERE TO INSTALL FORM-GARD

In most drive systems there are several alternate locations where the Form-Gard clutch can be installed (Fig. 2). The preferred position for Form-Gard is at the driven shaft. This location places the overload protection clutch at a point in the drive system where actual load torque can be accurately monitored. Alternate locations in the drive system as shown in Figure 2 are usually subject to greater variation in torque loads due to the reduction ratios within the drive system. The preferred mounting location will provide better control of the overload release torque thus preventing unnecessary release at torques below safe operating levels due to system inertia and starting torque peaks.

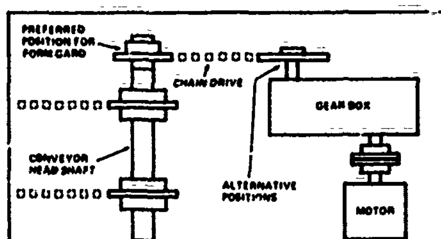


Fig. 2

REDUCTION GEARING

When Form-Gard Clutches are installed on large ratio reduction gear boxes care must be taken since it may not be practical to set a torque limiter mounted on the input shaft low enough to provide the proper torque protection on the output shaft. The large reduction ratio will also decrease the accuracy of the output release torque setting if the clutch is located on the input shaft.

HIGH INERTIA DRIVE SYSTEMS

When selecting Form-Gard for use in a high inertia drive system the location of the clutch must be between the high inertia load (flywheel, large pulley or gear, etc.) and the driven mechanism. Locating the Form-Gard overload release clutch in this position will protect the driven mechanism from the large inertia forces.

HOW TO SELECT

Select Manual Reset, Automatic Reset or PTO Mounted type overload release clutch to suit your specific application.

Choose a position in your drive system for the Form-Gard clutch. See page 13 for guidance.

Calculate the torque setting required for the position selected.

Calculate the maximum permissable torque for the drive components after considering torsional stress in shafting, stress on keys and keyseats, torque capacity of couplings, chains, gears, belts, etc. It is the weakest component in the system that requires protection.

—or—

Determine the torque setting based on motor horsepower, drive speed and reduction ratios calculating the drive torque.

$$\text{torque (lb. ft.)} = \frac{\text{horsepower} \times 5250}{\text{RPM}}$$

—or—

Determine the maximum permissable driven load based on conveyor belt or chain tension.

An allowance for starting torque may be required depending on the location of the clutch in the drive. At the motor shaft peak torques of approximately twice normal running torque is possible. At locations away from the motor peak torques will be damped by system inertia, tending to reduce the effect of motor peak starting torque. Field conditions will also tend to change the calculated torque values.

The best way to deal with the above variables is to make some allowance when selecting the torque setting required. Keep in mind that each Form-Gard clutch is adjustable and the final overload release torque setting can be adjusted on the job to meet your specific application requirements.

With the approximate torque required select the right size and type clutch from the tables on Pages 5 thru 11.

Check the clutch selected to make sure the shaft, key, sprocket, pulley or U-joint, etc. requirements of your application can be accommodated.

HOW TO ORDER

Please supply the following information with your order:

Quantity: The number of clutches needed.

Type /model / bore and keyseat. Example: Type JAB-7 / 1.625" bore / 3/8 × 3/16 keyseat

When combination units are selected supply additional data as required below:

For coupling combination supply bore and keyseat for coupling.

For sprocket or pulley combination supply complete sprocket or pulley data.

For Type "JF" clutch supply complete U-joint data.

Advise torque setting required.

Special requirements such as shifter ring, neoprene seals, etc. must be specified.

If bore and/ or keyseat sizes other than standard tolerances or shaft fits are required, please specify dimensions completely including tolerances. Standard shaft fits and bore tolerances are listed on page 15.

Please submit a completed application data sheet (forms available from Formsprag) for all Form-Gard Clutch applications which require torque, speed, bore, shaft fits, keyseats, or other special requirements not listed in this catalog.

STANDARD BORE & KEYSEAT DATA

PRICE LISTS REFER TO THESE STANDARDS

TYPE "JA" CLUTCH

CLUTCH SIZE	2	5	7	8	9
INDIVIDUAL STANDARD BORE SIZES	.625 .750 .875	.875 1.000 1.125 1.250	1.250 1.500 1.625 1.750 1.875	2.000 2.500	ANY BORE OR KEYSEAT WITH STD. TOLERANCE WITHIN BORE RANGE
MINIMUM BORE	.500	.750	1.250	1.500	2.000
MAXIMUM BORE	1.000	1.575	2.240	3.030	4.000

TYPE "JC" CLUTCH

CLUTCH SIZE	1	3
INDIVIDUAL STANDARD BORE SIZES	.375 .500	.625 .750 .875 1.000
MINIMUM BORE	.250	.500
MAXIMUM BORE	.625	1.125

TYPE "JF" CLUTCH

CLUTCH SIZE	4
INDIVIDUAL STANDARD BORE SIZES	.875 1.000 1.125 1.250
MINIMUM BORE	.750
MAXIMUM BORE	1.500

STANDARD TOLERANCE ON ALL BORE SIZES WILL BE NOMINAL BORE – .000 / + .001 INCH.

STANDARD KEYSEAT TOLERANCES

All Sizes	Width	+ .002 - .000
All Sizes	Depth	+ .010 - .000

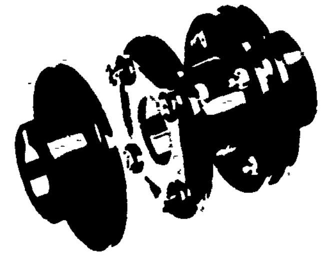
STANDARD KEYSEATS (INCHES)

Nominal Shaft Diameter		Keyseat	
Over	Thru	Width	Depth
3/8	7/16	3/32	3/64
7/16	9/16	1/8	1/16
9/16	7/8	3/16	3/32
7/8	1-1/4	1/4	1/8
1-1/4	1-3/8	5/16	5/32
1-3/8	1-3/4	3/8	3/16
1-3/4	2-1/4	1/2	1/4
2-1/4	2-3/4	5/8	5/16
2-3/4	3-1/4	3/4	3/8
3-1/4	3-3/4	7/8	7/16
3-3/4	4-1/2	1	1/2
4-1/2	5-1/2	1-1/4	5/8
5-1/2	6-1/2	1-1/2	3/4

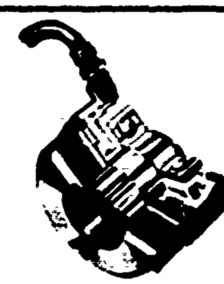
SPECIAL BORE AND KEYSEAT

All units can be supplied with special bore and keyseat sizes to meet your specific application requirements in both English and Metric sizes. Full shaft and keyseat details including tolerances must be supplied with order.

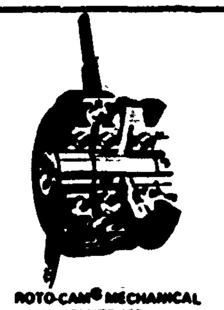
OTHER FORMSPRAG-MT. PLEASANT POWER TRANSMISSION PRODUCTS



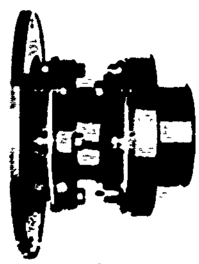
FORM-FLEX™ COUPLINGS



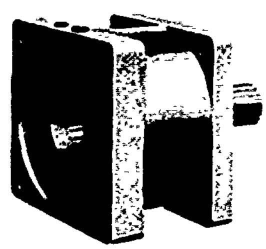
DISCO-TORQUE® HYDRAULIC PNEUMATIC CLUTCHES



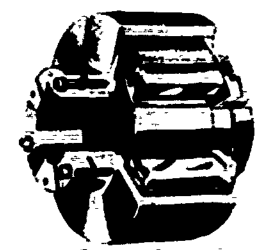
ROTO-CAM® MECHANICAL CLUTCHES



FORM-FLEX™ CENTURY COUPLINGS



DISCO-TORQUE® HYDRAULIC DISCONNECT CLUTCHES



NLS® (NO LOAD START) CENTRIFUGAL CLUTCHES

Formsprag Warranty

Formsprag Company guarantees all its products will leave the factory in good condition. Formsprag warrants its products against defects in workmanship and material for a period of 365 days (one year) after shipment. Adjustments under this warranty will be made only after completion of inspection of the part or product in Formsprag's factory. Formsprag's liability under the warranty shall extend only to the replacement or correction of any defective part or product determined by Formsprag inspection as not conforming to this warranty.

This warranty shall not apply to any product which shall have been repaired or altered without Formsprag's knowledge and consent or operated or installed contrary to Formsprag's instruction or subjected to misuse, improper maintenance or is damaged by accident or negligence.

This warranty is made in lieu of all other warranties, express or implied, including but not limited to warranties of merchantability or fitness for a particular purpose, and there are no other warranties that extend beyond this express warranty.

Formsprag Company reserves the right to discontinue models or to change specifications at any time without notice. No discontinuance or change shall create any liability on the part of Formsprag in respect to its products in the hands of its customers or products on order not incorporating such change even though delivered after any such change.

Performance Assurance

Rated torque and speeds of Formsprag products are provided in current catalogs to assist the buyer in selecting the proper Formsprag product. In addition, application engineering assistance is offered by Formsprag Company for guidance to the buyer in selection of a catalog product and for design and application of custom designed couplings. Since the actual performance characteristics of the buyer's equipment cannot be reproduced in Formsprag testing laboratories, performance assurance of all Formsprag products in the buyer's application is the responsibility of the buyer. Performance assurance is usually accomplished through manufacture of a prototype by Formsprag, and a test or qualification program on the part of the buyer.

Rotating equipment is potentially dangerous and should be properly guarded. The user should check for all applicable safety codes in his area and provide a suitable guard.

Formsprag
Mt. Pleasant
DANA
DIVISION OF DANA CORPORATION

801 E. INDUSTRIAL DR. • MT. PLEASANT, MICHIGAN 48858
TELEPHONE (517) 773-5931 • TELEX 227447

CANADIAN SALES: 17 VALOIS BAY AVENUE
PT. CLAIRE, PQ H9R 4B4 CANADA
(514) 695-7602

10M-4/76 – 1st Edition

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Litho in U.S.A.

4.9 <u>Helland Torq-Tender, Reference Fig. #11</u>

4.9.1 The Helland Torq-Tender is a positive mechanical device which uses a detented key that is radially opposed by (2) counteracting compression springs for transmitting limited torque in either direction of rotation.

4.9.2 Two models, TT3 and the Tandem are required to cover the 3 through 10 H.P. drive range. Also, a large quantity of trip release springs are required to cover the torque range.

4.9.3 The torque setting is not externally nor infinately adjustable. To change a spring requires complete removal of the unit from the drive system.

4.9.4 Periodic maintenance for lubrication, due to running in excess of 500 RPM, also requires complete removal of the unit from the system.

4.9.5 Preferred features are,

(a) Different torque settings for forward and reverse movement.

(b) Can be sealed (dustproof or waterproof).

(c) All position mounting.

(d) All steel construction.

(e) Automatic reset (below 25 RPM).

(f) Accepts 1½$^{\circ}$ angular to .015" parallel misalignment.

(g) Automatic shut-off.

(h) Tamperproof setting.

(j) Ambient temperature range of sub zero to +350° F.

(k) Cadmium plating or stainless steel construction for corrosion resistance.

4.9.6 The bore range for both models is 1 1/8" maximum and requires adapters for both motor and reducer shafts. Installation area required between shafts is 5 to 5¼".

Effective overload protection in most any environment . . .

HELLAND TORQ-TENDER is a positive mechanical unit, designed to maintain accuracy in any position, any atmospheric or moisture condition, under frequent or infrequent overloads and in a variety of other situations often encountered.

HIGH TEMPERATURES do not slow the instant response of the Torq-Tender. One large in-plant installation sees them protecting a complete production line of hot glue extruders which operate at 350 F.

LOW TEMPERATURES do not affect the dependability of these Helland units. Through the sub-zero cold of artic winters Torq-Tenders protect the drive mechanisms of radar tracking antennas.

SMALL SPACE is all that's required. Because of its favorable torque capacity and compact size, the Torq-Tender has been chosen to protect the camera controls on one of this nation's most sophisticated under-sea laboratories.

FREQUENT OVERLOAD is no problem. In a variety of manufacturing plants where assembly is critical it's common to rely on Helland Torq-Tenders for the control of torque in nut-running operations.

DUSTY ATMOSPHERE does not change the pre-set torque setting. Dust-proof models are available where required, though standard units are frequently used for applications such as mine conveyors and construction equipment.

OILY ATMOSPHERE, *in which a friction unit cannot survive,* is home for a Torq-Tender. Lathes, milling machines and other cutting tools are ideal applications for this Helland unit.

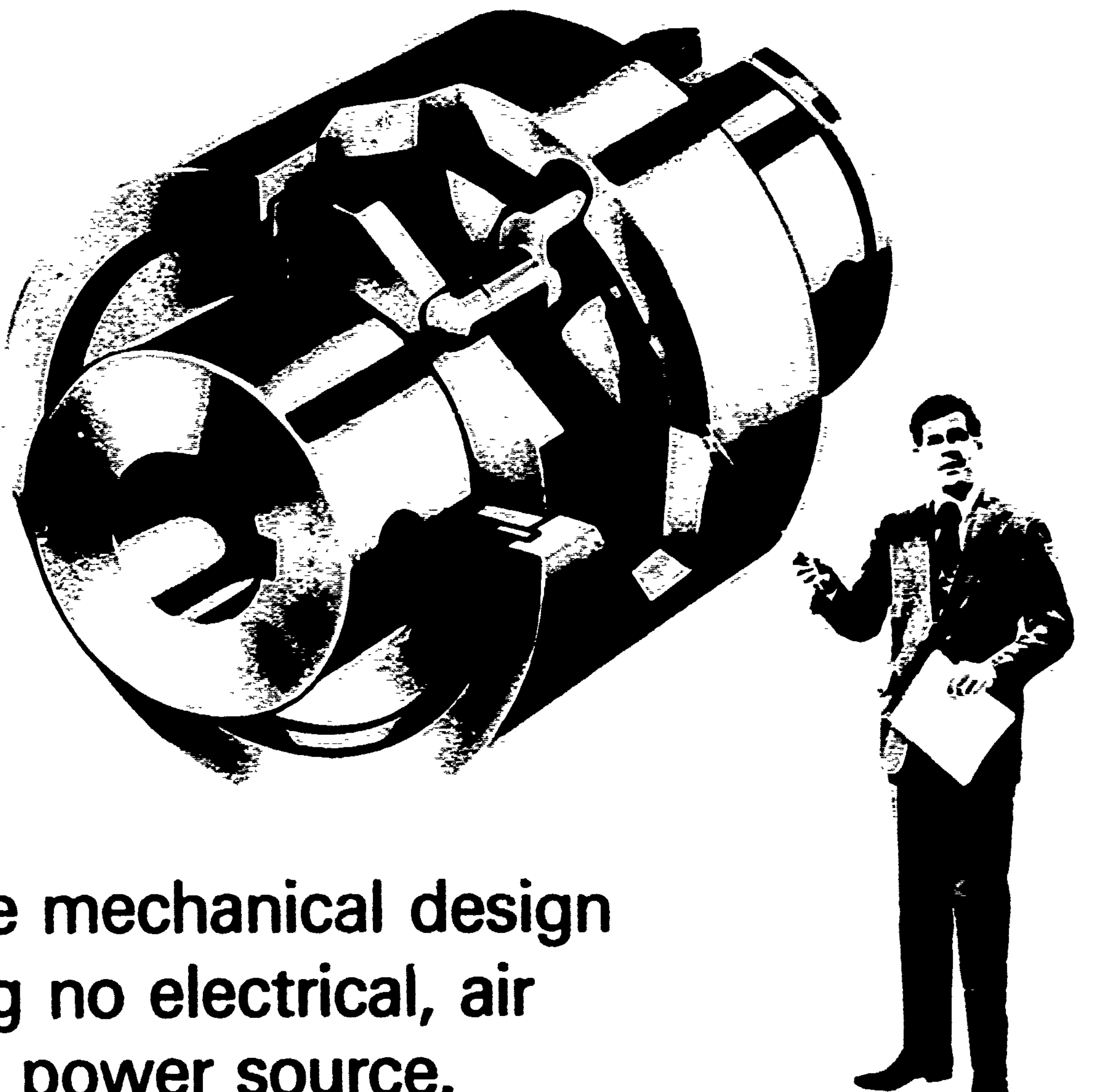
HIGH HUMIDITY does not dampen the accuracy of the Torq-Tender. Even dairy equipment, which must be steam cleaned on a daily basis, is protected from overload by these dependable Helland units.

SALT WATER, an unfriendly environment for mechanical devices of all kinds, fails to hamper the action of the Torq-Tender. Helland provides stainless steel units to protect the drive components of salt water drilling equipment.

HIGH SPEED installations such as bottling machines, can testing devices and other process equipment operate at minimum down time when Torq-Tenders arrest overloads, prevent jam-up and re-set automatically.

FORWARD/REVERSE does not matter. Torq-Tenders respond accurately in either direction. If, such as in drilling or tapping installations, a different torque requirement is indicated for reverse it can be accomplished by the change of just one spring.

HELLAND
TORQ-TENDER®



a unique mechanical design requiring no electrical, air or other power source.

The Torq-Tender is a positive drive coupling that provides accurate overload protection or torque limiting. It is not a friction clutch and therefore maintains its accuracy after thousands of disengagements. It is compact and easy to install. It operates in any position and both rotational directions. No tools are required for resetting as the Torq-Tender returns to its predetermined torque merely by removing the overload and slowing the driving unit.

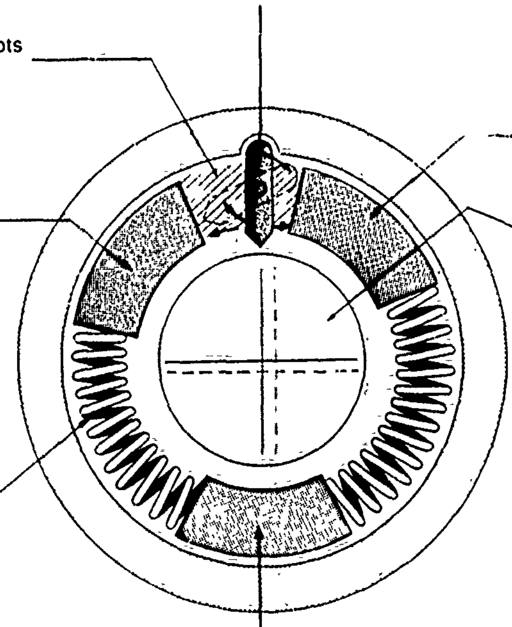
Six standard sizes offer a range of torque limits from 1 inch-pound to 3,000 inch-pounds. All are available in dust-proof or water-proof models, in special configurations and with plated exposed surfaces at slight additional cost.

Torq-Tender couplings are manufactured under one or more of the following patents U.S. #3,124,227, 3,301,362 and 3,147,834. Foreign and other U.S. patents pending. All patents are owned by Helland Research and Engineering, Inc.

No friction unit can match the dependability of a

TORQ-TENDER®

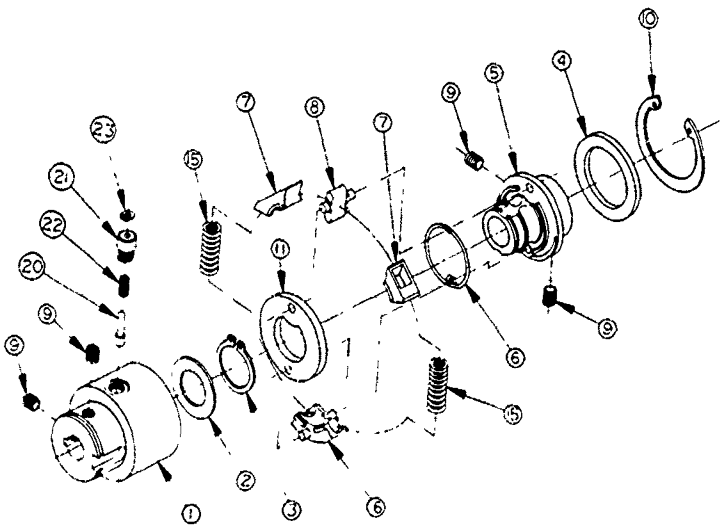
Here's why:



Torque rating returns to the exact original value regardless of the number or frequency of overloads.

Helland Research and Engineering, Inc.

TORQ-TENDER® Standard parts list



① Housing ② Thrust Washer ③ Retaining Ring ④ Line Up Washer ⑤ Drive Shaft ⑥ Return Spring ⑦ Spring Slide ⑧ Drive Key ⑨ Set Screw ⑩ Retaining Ring ⑪ Race Ring ⑮ Compression Spring ⑯ Spring Stop ⑳ Actuating Pin Shaft ㉑ Actuating Pin Housing ㉒ Actuating Pin Compression Spring ㉓ Actuating Pin Retaining Ring

Versatile Torque Control

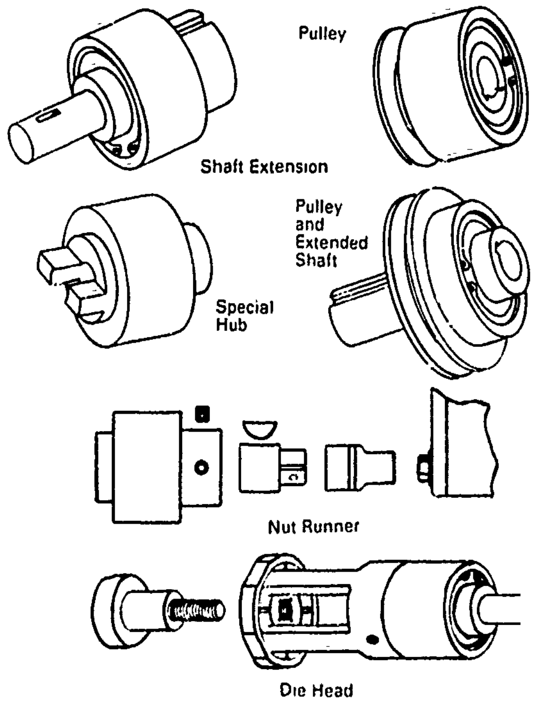
TORQ-TENDER COUPLINGS are used to:

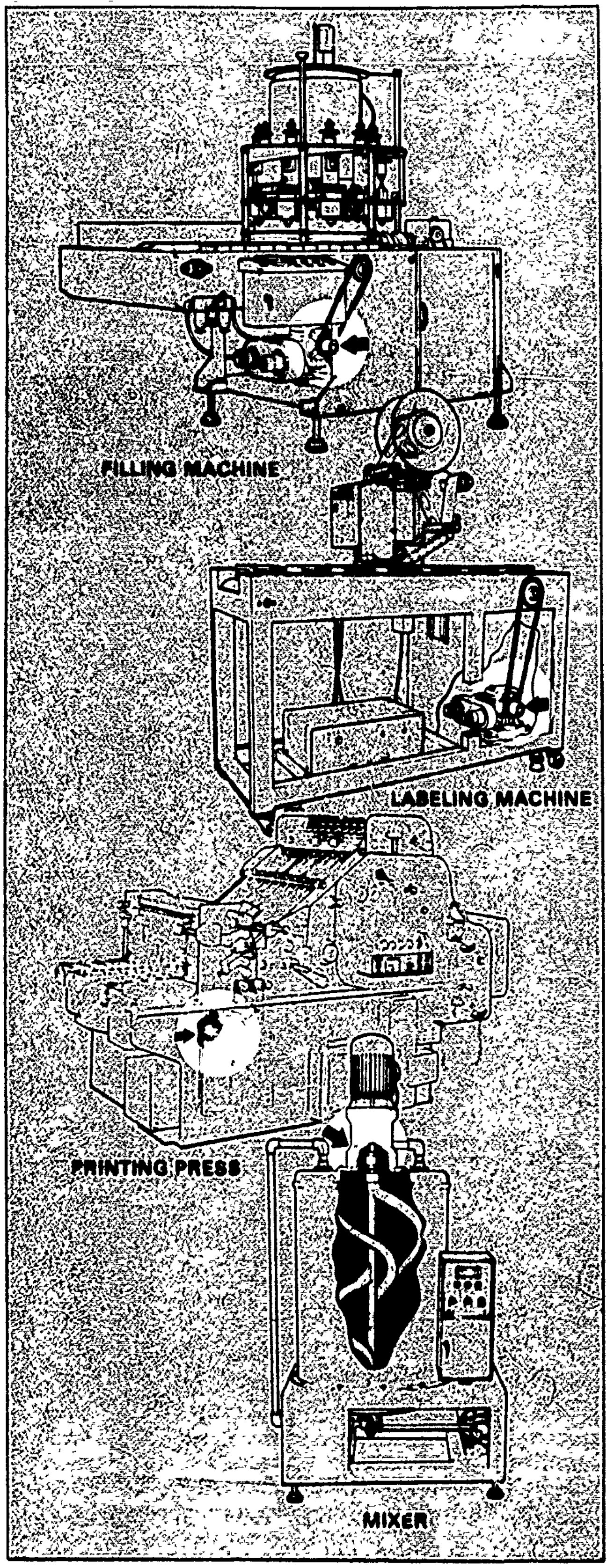
- Protect motors
- Protect cutting tools
- Protect tables and carriage mechanisms
- Protect drilling and tapping tools
- Protect gear reducers — drives
- Protect conveyors
- Protect tumblers and turntables

TORQ-TENDER COUPLINGS are used on:

- Lathes
- Milling machines
- Mixers
- Drills
- Conveyors
- Tumblers
- Turntables
- Packaging machines
- General drives
- Ovens
- Textile machines
- Floor machines

TORQ-TENDER® couplings can be made up in many special configurations, a few examples shown here.





WARRANTY

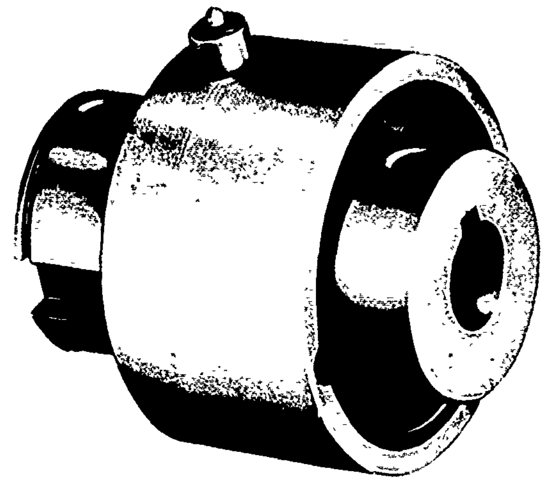
Parts and performance of each Torq-Tender® coupling are warranted for 6 months when used in accordance with instructions Warranty is void if the Torq-Tender® coupling has been altered or reworked Warranty covers only the repair or replacement of the Torq-Tender® coupling. Transportation is not allowed.

Standard Advantages of the Helland **TORQ-TENDER®**

1. Accurate trip release
2. Torq-Tenders will solve most overload problems
3. No adjustments required as torque setting remains constant
4. Will last for years
5. Single position for machine timing
6. Small diameter — strong torque
7. Easy to install
8. Easy to mount gear, pulley or sprocket (see drawing page 7)
9. Standard units function in temperatures up to 350°
10. Serves as a flexible coupling — 1½° angular misalignment and .005° to .030° parallel misalignment, depending upon the size of the unit
11. Will function in a vertical or horizontal position
12. Can be used as an indirect coupling as well as a direct coupling
13. Torq-Tender will function in both clockwise and counter clockwise direction
14. Standard bore sizes of Torq-Tenders will fit most shaft diameters
15. Resets automatically once overload is removed and speed reduced
16. An optional actuating assembly which strikes a switch and activates a warning signal or shuts off the motor can be provided at small additional cost (see page 6)

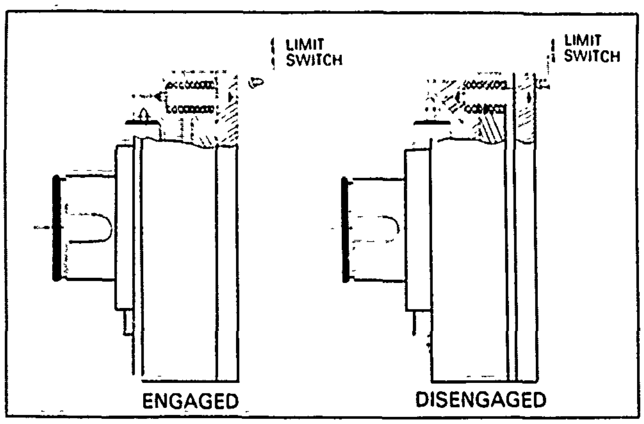
Construction

Torq-Tender couplings are built to high industrial standards and will last for years with only minimum maintenance required. Drive key and spring slides are investment castings of hardened steel. Housing and hub are mild steel, case hardened. Springs are carefully selected to give accurate torque settings. Water and dust proofed construction are available for a small additional charge. Torq-Tender couplings function in ambients up to 350° F. All units are available with Bronze Oilite Bearings in housing bore for through-shaft installations, in which the single shaft must extend to the end of the housing bore to support overhung loads. This is an ideal application for mounting a gear, sprocket or pulley.



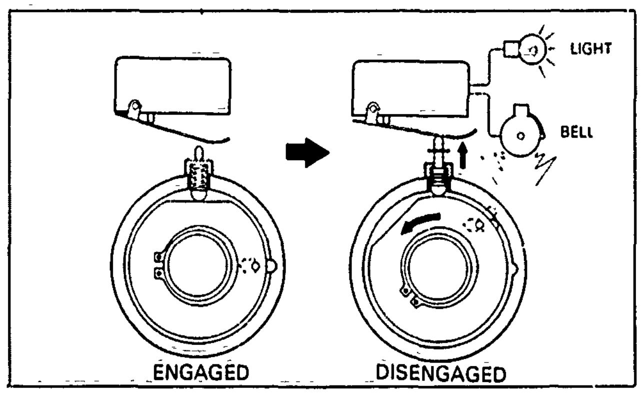
Provides Automatic Shut-Off Too!

ACTUATING DISC



The basic Helland Torq-Tender Clutch with Actuating Pin is used with a second pin installed 180° to the first pin. The ACTUATING DISC is mounted on the outside diameter of the Torq-Tender so that when overload occurs, both actuating pins force a sliding member axially an amount equal to the pin ejection. The limit switch is mounted so that the sliding member actuates the switch immediately upon overload thereby shutting down the machine. The unit resets automatically upon reengagement and is bi-directional. This design allows either end of the Torq-Tender to be used as the input end.

ACTUATING PIN



An Actuating Pin is available as an optional feature on the six largest models of the Helland Torq-Tender. The instant an overload occurs, the actuating pin becomes operative, traveling ⅛" to strike a limit or mercury switch that will actuate a warning signal or shut off the motor.

When the Fail-Safe Pin is used, the Torq-Tender coupling should be installed so that the "F" bore is the input and the "C" bore the output thus allowing the pin mechanism to rotate and strike the switch. When ordering the Torq-Tender with the Fail-Safe Pin, "C" and "F" dimensions must be specified (see dimensional drawing, page 9).

After the overload situation is corrected, the Torq-Tender coupling automatically synchronizes the original setting at the exact previous location and torque rating and the Fail-Safe Pin retracts to its original position.

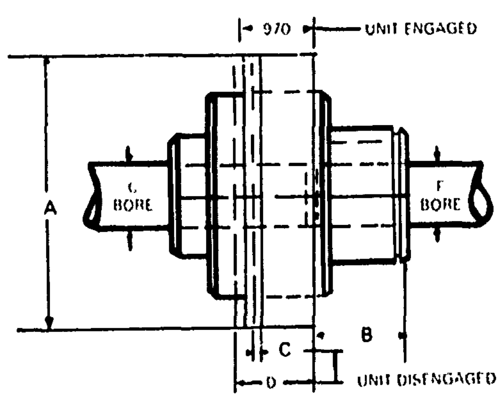
Dimensions

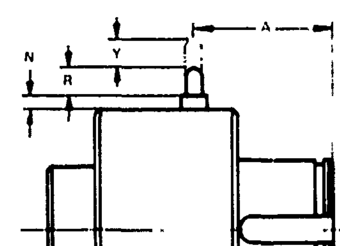
ACTUATING DISC

MODEL	A	Y	R	N
TT—1X	.850	0.094	0.250	0.250
TT—2	1.094	0.125	0.187	0.250
TT—2X	1.375	0.125	0.125	0.250
TT—3	1.625	0.125	0.125	0.187
TANDEM	1.625	0.125	0.125	0.187
TT—4X	2.000	0.125	0.135	0.075

ACTUATING PIN

MODEL	A	B	C	D
TT—1X	2.985	.687	3/32	1.063
TT—2	3.485	.893	1/8	1.097
TT—2X	3.935	1.175	1/8	1.097
TT—3	4.480	1.425	1/8	1.097
TANDEM	4.480	1.425	1/8	1.097
TT—4X	6.250	1.690	1/8	1.312



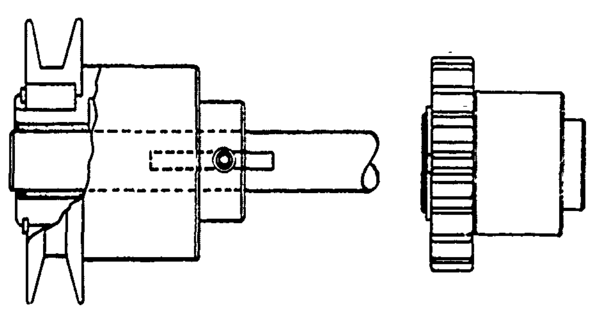


Ask us for your special requirements

1. Plated — nickel, chrome, zinc, cadium, etc.
2. Special material such as stainless steel
3. Multiple re-engagement
4. Metric and non standard bores and keyways
5. Torque ratings — different torques for forward & reversing applications
6. High temperature lubrication and seals
7. Can be sealed to make dust and water proof

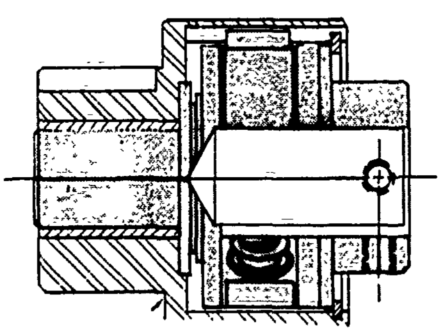
Whatever your requirements, we'll tailor-make a Torq-Tender® for you!

Instructions for Mounting Gear, Pulley or Sprocket



A. Shown is Pulley and Sprocket or Gear mounted on flange with Bronze Oilite Bearing in bore (See CONSTRUCTION, Page 4).

Above is a typical application showing a pulley, sprocket or gear mounted on the flange with an oilite bearing pressed in the housing (F) bore. Because the Torq-Tender must be supported on both ends, the shaft must extend the complete length of the unit, thereby supporting the outer end of the unit. Upon overload, the housing end revolves on the shaft. Refer to illustration B for the application where the shaft is too short to extend through the Torq-Tender.



B. Shaded area is one piece drive shaft supported with Oilite bushing

Shown above is the self-supporting Torq-Tender to be used in applications where the shaft is too short to completely support the outer end of the Torq-Tender. The shaded area is a one piece drive shaft which supports the outer end of the Torq-Tender. A pulley, gear or sprocket is then mounted on the flange as in illustration A. This self-supporting unit is now available in the TT-2 and TT-3 models.

Instructions for determining torque rating required and TORQ-TENDER® model number for your application.

Computation of the RPM's should be made according to the location you select for the Torq-Tender.

1. Refer to the following table to obtain the running torque rating of your application — the rating required to determine the proper strength of Torq-Tender springs.
2. From the chart headed Torque Ratings Available determine which models provide the desired overload protection for your application.
3. Select the model with the dimensions that most closely match the needs of your application.
4. Indicate a unit with a fail-safe actuating pin where automatic warning or shutdown is required.

MAXIMUM RUNNING TORQUE IN INCH POUNDS FOR VARIOUS HORSEPOWER MOTORS

	HORSEPOWERS														
RPM	1/4	1/3	1/2	3/4	1	2	3	4	5	6	7	8	9	10
5															
10	1528	2106													
15	1050	1400	2100												
20	764	1050	1528	2360											
25	631	841	1261	1890	2522										
30	525	700	1050	1572	2100										
35	450	600	900	1348	1800										
40	394	526	789	1178	1578										
45	350	467	700	1050	1401	2802									
50	316	420	631	945	1261	2522									
60	262	350	525	789	1050	2100									
70	225	300	450	675	900	1800	2700								
80	197	293	394	590	789	1580	2367								
90	175	233	350	525	700	1402	2100	2804							
100	157	210	315	422	630	1261	1891	2521							
150	105	140	210	315	420	840	1261	1681	2101	2521	2941				
200	79	105	157	236	315	630	945	1261	1575	1891	2206	2521	2836		
250	63	84	126	189	252	504	756	1008	1260	1513	1765	2017	2269	2521	
300	52	70	105	157	210	420	630	840	1050	1261	1471	1681	1891	2101	
350	45	60	90	135	180	360	540	720	900	1080	1261	1441	1621	1801	
400	39	53	79	118	158	315	473	630	788	945	1104	1261	1418	1576	
450	35	47	70	105	140	280	420	560	700	840	980	1120	1261	1401	
500	31.5	42	63	95	126	252	378	504	630	756	882	1008	1134	1261	
550	29	38	57	86	115	229	344	458	573	688	802	917	1031	1146	
600	26	35	52	79	105	210	315	420	525	630	735	840	945	1050	
650	24.2	32	48.5	73	97	194	291	388	485	582	679	776	873	970	
700	23	30	45	67.5	90	180	270	360	450	540	630	720	810	900	
750	21	28	42	63	84	168	252	336	420	504	588	672	756	840	
800	19	26	39	59	79	158	236	315	394	473	551	630	709	788	
850	18.5	25	37	55.5	74	148	222	297	371	445	519	593	667	741	
900	17.5	23	35	52 5	70	140	210	280	350	420	490	560	630	700	
950	17	22	33	49	66	133	199	265	332	398	464	531	597	663	
1000	16	21	31	47	63	126	189	252	315	378	441	504	567	630	
1100	14	19	28	43	57	115	172	229	286	344	401	458	516	573	
1200	13	17.5	26	40	53	105	158	210	263	315	468	420	473	525	
1300	12	16	24	36	48	97	145	194	242	291	339	388	436	485	
1400	11.2	15	22.5	34	45	90	135	180	225	270	315	360	405	450	
1500	10.5	14	21	31	42	84	126	168	210	252	294	336	378	420	
1600	10	13	19.6	29	39	79	118	158	197	236	276	315	355	394	
1700	9.5	12.5	18 5	28	37	74	111	144	185	222	260	296	334	371	
1750	9	12	18	27	36	72	107	142	180	216	252	288	324	360	
1800	8	11	17	26	35	70	103	140	175	210	245	280	315	350	

HOW TO USE TABLE:

1. 1HP at 50 RPM:
   Read across the 50 RPM line to the 1 HP column. Running torque is equal to 1261 inch pounds.
2. 25 HP at 600 RPM:
   Read across the 600 RPM line to the 5 HP column. Running torque to be encountered is five times the amount shown or 525 times 5, the equivalent of 2625 inch pounds.
3. 12½ HP at 600 RPM:
   Read across the 600 RPM line adding the values found at the ½ HP, 2 HP and 10 HP columns to arrive at the total running torque for 12½ HP. (52 plus 210 plus 1050 equals 1312 inch pounds total running torque).

Instructions For Installing TORQ-TENDER®

It is preferable to mount the unit on the output shaft of the motor or speed reducer with the drive shaft side toward the motor or speed reducer. The direction of the unit can be reversed when used as a coupling. The speed reducer and the driven shaft should be well lined up for mounting of the Torq-Tender but the unit does serve as a flexible coupling for both parallel and angular misalignment. All sizes of Torq-Tenders will accept up to 1½ degrees of angular misalignment. But parallel misalignment varies according to size of the units as follows: T-T-1—.005", T-T-1X—.007", T-T-2—.010", T-T-2X—.015", T-T-3—.030", T-T-4X—.030". When a gear, sprocket or pulley is mounted on the hub of the housing, the output shaft should extend through the unit with an oilite bearing supporting the overhung load.

There's no trick to re-engaging a TORQ-TENDER®

The Torq-Tender develops a clicking sound when in a disengaged position, a warning of an existing overload. The unit will re-engage automatically when motor runs 25 RPMs or less but if running faster simply slow down or stop motor until it re-engages.

How to Order TORQ-TENDER® Couplings

1. Specify the catalog number.
2. Determine the torque rating required and then select from the torque values listed on page 10. If uncertain about torque, order additional springs of higher and lower torque ratings. These can be easily substituted.
3. Specify the bore size for the C bore (drive shaft) end.
4. Specify the bore size for the F bore (housing) end.
5. Specify if an oilite bushing is needed on the drive side for overhung load to support gear, sprocket or pulley.
6. Specify if an actuating pin or actuating disc assembly is to be included. See page 6 for specific instructions.
7. Specify delivery time and shipping requirements. For special requirements, contact factory.

TABLE 1

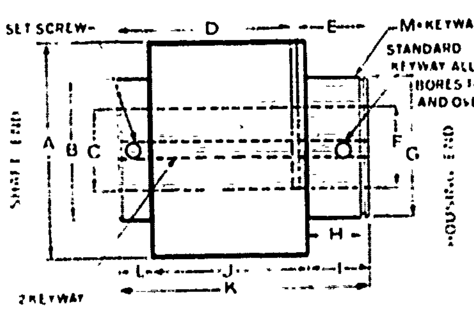
Catalog No.	Torque Range in Lbs.	C Bore	F Bore	Oilite Bushing	Actuating Assembly	Shipping Weight Lbs.
TT1	1 to 15	1/8 3/16 1/4 5/16	1/8 3/16 1/4 5/16	Specify	N/A	1/4
TT1X	2 to 60	3/16 1/4 5/16 3/8 7/16 1/2	3/16 1/4 5/16 3/8 7/16 1/2	Specify	Specify	1/2
TT2	4 to 140	1/4 5/16 3/8 7/16 1/2 5/8	1/4 5/16 3/8 7/16 1/2 5/8	Specify	Specify	1-1/4
TT2X	18 to 350	1/2 5/8 3/4	1/2 5/8 3/4	Specify	Specify	2-1/4
TT3	18 to 500	3/4 7/8 1 1-1/8	3/4 7/8 1 1-1/8	Specify	Specify	3-1/4
Tandem	240 to 1000	3/4 7/8 1 1-1/8	3/4 7/8 1 1-1/8	Specify	Specify	5
TT4X	750 to 3000	7/8 1 1-1/8 1-1/4 1-3/8 1-1/2 1-3/4	7/8 1 1-1/8 1-1/4 1-3/8 1-1/2 1-3/4	Specify	Actuating Pin Supplied	15

Keyway and Hub Dimensions

Bores under ½" will have no keyways. Bores ½" and over will have standard keyways as follows:

TABLE 2

Bore Size Inches	Keyway Width
Under 1/2	None
1/2 to 9/16	1/8"
5/8 to 7/8	3/16"
15/16 to 1-1/4	1/4"
1-5/16 to 1-3/8	5/16"
1-7/16 to 1-3/4	3/8"



Hub sizes and hub keyway sizes are as follows on housing end:

TABLE 3

Model No.	G Hub O.D.	M=Keyway Width
TT1	.625	3/16"*
TT1X	1"	1/4"
TT2	1-3/8"	5/16"
TT2X	1-5/8"	3/8"
TT3	1-3/4"	3/8"
Tandem	1-3/4"	3/8"
TT4X	3"	3/4"*

*Oilite Models only

NOTE: Bores under ½" are supplied with no keyway and one (1) set screw. Bores ½" and over are supplied with standard keyway and two (2) set screws.

Torq-Tender® Coupling

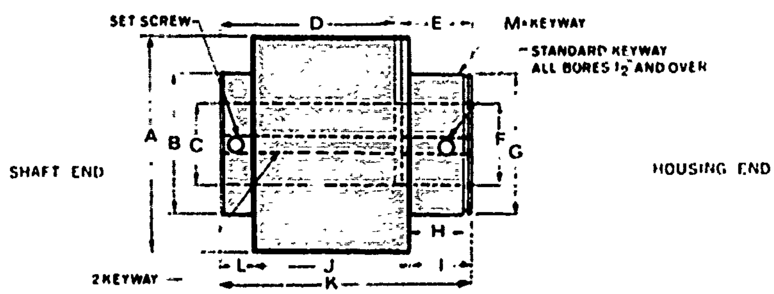
(TORQUE RATINGS AVAILABLE)

Trip Release Springs Available For Torq-Tenders:

TT1 Inch Lbs.	TT1X Inch Lbs.	TT2 Inch Lbs.	TT2X Inch Lbs.	TT3 Inch Lbs.	TANDEM Inch Lbs.	TT4X Inch Lbs.
1	2	4	18	18		
3	3	6	24	24		
5	5	8	28	28		
8	8	10	36	36		
10	10	12	40	40		
12	12	18	50	50		
15	15	25	60	60		
	18	30	90	65		750
	20	40	100	80	240	1000
	25	50	120	120	300	1250
	30	60	135	150	360	1500
	40	85	180	180	440	1750
	50	100	200	220	500	2000
	60	125	250	250	600	2250
		140	300	300	700	2500
			350	350	840	2750
				420	1000	3000
				500		

These springs can be easily removed and replaced by springs with the required torque. See back page. Springs are not interchangeable between TORQ-TENDER® couplings with different catalog numbers.

Dimensions

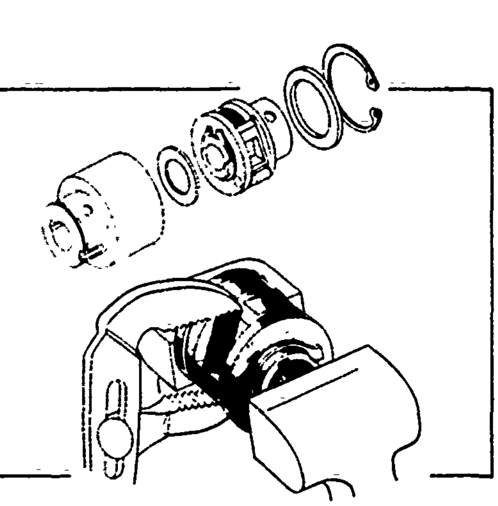


Standard Dimensions (in inches)

Size	A Body Dia.	B Hub Dia.	C Bore and Keyway	D Hub Engagement	E Housing Engagement	F Bore and Keyway	G Hub and Keyway	H Hub Length	I Flange Length	J Body Length	K Overall Length	L Hub Projection
TT1	1.000	.625	See Tables 1 & 2, Page 9	.812	.512	See Tables 1 & 2, Page 9	See Table 3, Page 9	.500	.500	.750	1.450	.200
TT1X	1.562	.875		1.125	.625			.500	.600	.985	1.790	.205
TT2	2.062	1.250		1.500	.812			.625	.750	1.300	2.450	.325
TT2X	2.500	1.500		1.750	1.125			.875	1.000	1.500	2.976	.450
TT3	3.000	1.750		2.000	1.312			1.062	1.187	1.812	3.475	.500
TANDEM	3.000	1.750		3.312	1.312			1.062	1.187	3.032	4.719	.500
TT4X	4.625	3.000		3.500	1.750			1.125	1.330	3.500	5.530	.700

CAUTION: When using Torq-Tender for direct coupling be sure shafts do meet inside unit. See dimensions D and E for proper engagement.

INSTRUCTIONS for changing springs



To remove springs, first remove retaining ring from the housing by drawing the retaining ring together with retaining ring pliers and remove the drive shaft from the housing. Then place the drive shaft in a vise. Pinch the springs with a pair of narrow jawed channel lock pliers, unseating and removing them.

To insert new springs, place the drive shaft in a vise and place one end of the spring against the bottom of the spring slot. Using a vise grip or similar pair of pliers, put the lower jaw under the drive shaft and the upper jaw on top of the other end of the spring. Compress the spring by closing the pliers and use a screw driver or blunt instrument to push the end of the spring out of the pliers into the spring slot. Repeat on other side.

When reassembling TORQ-TENDER®, make sure the thrust washer is in place in the groove in the housing. The housing should be properly lubricated with No. 2 Lubriplate with molydisulphite.

LUBRICATION INSTRUCTIONS. Your TORQ-TENDER® is shipped properly lubricated with No. 2 Lubriplate with molydisulphite. Where overloading is infrequent, no additional lubricant is required. Where frequent overloading occurs, especially at speeds in excess of 500 RPM, periodic lubrication is necessary. Follow the procedure for opening the TORQ-TENDER® stated above. Brush a liberal coating of lubricant inside the housing and reassemble. For moist or dirty atmospheres, specify rubber "O" rings to seal out moisture and dirt and to help retain the lubricant.

5. Torque Limiter Comparison and Selection

5.1 In comparison, the previously reviewed units meet most of the requirements except for a few specific features.

5.2 Dalton OSDC Torque Limiter

This unit, the most simplest and economical of all reviewed, cannot maintain an accurate setting and by design is not adaptable to activating a motor shut off switch. Its incapability to meet these two requirements, eliminate friction disc type clutches from this selection.

5.3 Helland Torq-Tender

The Torq-Tender unit is unique in design and has several features that no other unit has, in that separate torque settings can be selected for forward or reverse operation and the unit is tamperproof. However, the fact that torque adjustment and maintenance requires extra parts and complete removal from the drive system, makes this unit a less desirable unit than the three remaining devices.

5.4 The (3) remaining units all use a positive ball detent type design in conjunction with one or more coil springs which are externally adjustable. The torque range of all three units covers the horsepower range of 2.25 thru 9.79 required for the 20 to 90 ft. conveyor range in height. Pricewise, all (3) basic torque limiters are in the same range of approximately $150.00 to $200.00.

5.5 Beyond this point there are certain features or requirements where each manufacturer differs from the other.

5.6 The features involved are,

(a) Accuracy of setting:

Autogard is ± 10% (this percentage might improve after break-in)

Rite-Torq - ± 5%

Form Gard - ± 5%

(b) Method of maintaining setting:

Autogard - set screw

Rite-Torq - locking ring tab

Form Gard - set screw over plastic plug

(c) Totally enclosed standard unit:

Autogard - No (could be enclosed if needed)

Rite-Torq - Yes

Form Gard - Yes

(d) Maintenance:

Autogard - clean and lubricate (scheduled maintenance)

Rite-Torq - none

Form Gard - none

(e) Capable of withstanding frequent overload, using a motor cutoff switch at 1800 RPM:

Autogard - Yes, but questionable, reference para. 4.6.7

Rite-Torq - Yes (tested), reference para. 4.7.3

Form Gard - Yes, although word of caution is advised, reference Fig. #10

5.7 It appears that Ferguson, Rite-Torq, backed by their own testing information, are more sure of their overload wear capabilities. Although it is possible that both Autogard and Form Gard are more cautious in making a direct statement along these lines, it is apparent that both makes use a ball location pattern to alleviate wear in this area.

5.8 Based on the above information, Ferguson, Rite-Torq Torque Limiter Model "S" Size 2 was selected for application in the drive system.

5.9 Kornylak Corporation drawing (2-1026-321F Rev. - Sht. 1 of 1) of the torque limiter assembly, shows the above unit attached to a rigid type reducer shaft adaptor per drawing 2-1026-335F. This adaptor should be replaced with a flexible coupling to allow for shaft misalignment.

6. Electrical Overload Device Selection

6.1 With the conveyor system mechanically protected to within 140 to 150% of rated full load, a supplementary electrical overload control, capable of being set to within 110 to 115% of full load is required.

6.2 Furthermore, the type of monitoring device selected should be reliable, easy to set and adjust, economical and above all failsafe in operation.

6.3 Past electrical and/or electronic type overload protection has been provided by several different devices, ranging from a highly sophisticated Tipptronic Control to a current sensing relay used in conjunction with a timing relay for bypassing the initial surge of current to start the motor.

6.4 The main drawback to the Tipptronic unit was trouble shooting and maintenance, due to its complexity. The more common type of relay, Allen-Bradley Bul. 809, provides a simple and rather inexpensive overload device, however, they are less accurate in both setting and repeatability. The list price for the relay and time delay is $120.00.

6.5 Newer approaches to power monitoring to be reviewed and compared are, Formsprag's TorQalert and a motor and load torque analyzer, manufactured by RFD Instrument Company in Elgin, Texas.

6.6 The TorQalert unit (reference Bulletin X-3012A) is a solid state device which integrates the motor input voltage and current to monitor the motor output power which is directly related to torque. The unit is easy and simple to adjust with a meter readout and also has a built-in time delay for motor startup. The price of this unit is approximately $230.00 per unit.

6.7 The motor and load torque analyzer by RFD Instrument Company (reference Bulletin RFD2002) detects an overload condition by the slip characteristics of the motor with a transducer in close proximity to the motor shaft. This method is entirely independent of voltage and horsepower. The unit is also solid state with a meter readout. The accuracy of this unit is ± 1% of relative set value. The list price is in the neighborhood of $600.00 per unit.

6.8 The motor to be monitored is a 3 speed constant torque 440V, 3 PH, 60 HZ design B motor. The horsepower, speed and full load amp ratings are listed below.

H.P.	SPEED	F.L.A.
10.0, 6.6, 5.0	1800, 1200, 900	15.4, 10.6, 15.0
7.5, 5.0, 3.75	1800, 1200, 900	11.5, 8.0, 11.0
5.0, 3.3, 2.5	1800, 1200, 900	7.3, 5.0, 7.0
3.0, 2.0, 1.5	1800, 1200, 900	5.0, 3.2, 5.0

6.9 Normally a 3-speed motor would require (3) separate overload controls, however, note that the full load amp rating for each motor is nearly the same for either 1800 or 900 RPM. With this in mind, one trip setting could be selected for the two amp ratings that would satisfy both speeds within the 110 to 115% overload range. For example, a setting of 17.1 amps on the 10 H.P. motor would be a 111% overload setting @ high speed and 114% @ low speed. Under this condition, only two TorQalert units are required per controller.

7.0 Although the RFD unit is highly more accurate, it is our opinion that the TorQalert unit with ± 5% accuracy is suitable for this application. Not only is it more pratical, it also offers simplicity both in selection of setting as well as installation.

BULLETIN X-3012-A
OCTOBER, 1975

INSTALLATION AND MAINTENANCE INSTRUCTIONS FOR OD MODELS

the professionals in motion

FORMSPRAG®

torQalert™
LOAD MONITOR OVERLOAD PROTECTION

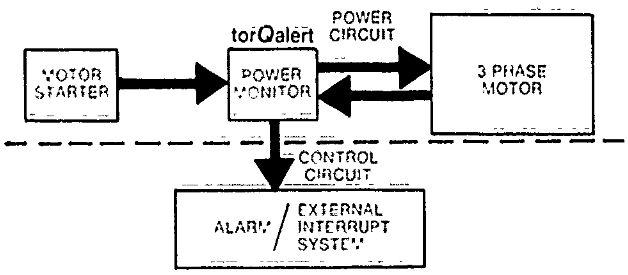
BEFORE YOU BEGIN INSTALLATION . . .

Keep in mind the block diagram below. The TorQalert has two electrical circuits associated with it: The power circuit and the control circuit.

The power circuit is the input to the TorQalert and *must be wired* as described in section A of the following pages.

The control circuit is the output of the TorQalert and utilizes the output contacts of the relay. The control circuits described in section B of this manual are only uses for the output contacts of the relay. Other uses of the TorQalert output contacts are limited only by the imagination.

BLOCK DIAGRAM



SECTION A — THE POWER CIRCUIT

1. Mount the unit in a location that is easily accessible to the wiring of the motor to be monitored. (electrical control box, if possible).

2. Choose the system from figures B or D that is your application. Figure B is a direct on line wiring diagram corresponding to a one direction motor. Figure D is a two direction wiring diagram employing reversing starters.

3. Consult the maximum continuous current column of table A. If the continuous current rating of the motor falls into this range, connect Phase I to the appropriate terminals found in table A. If the continuous current rating is higher than this range, obtain a current transformer (2VA min) with a reduction ratio that will reduce the current to this range. Install the current transformer as shown in fig. C and connect its leads to the corresponding terminals found in table A.

TABLE A

CONNECTIONS TO TERMINALS 5-6-7		
TERMINALS	MINIMUM RATED CURRENT OF MOTOR (A)	MAXIMUM CONTINUOUS CURRENT (A)
5; 7;	2.0	4.0
6; 7;	3.0	6.0
5; 6;	5.0	7.5

4. To complete the power circuit, connect Phases II and III to terminals 4 and 3 respectively. *NOTE.* that in the reversing starters diagram, terminals 3 and 4 are connected on opposite sides of the starters.

DO NOT ATTEMPT TO TEST THE UNIT UNTIL YOU HAVE READ SECTIONS B & C

POWER CIRCUITS

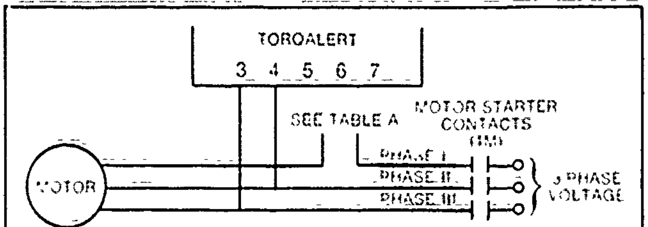


FIG. B DIRECT ON LINE

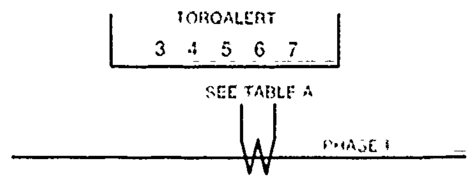


FIG. C CURRENT TRANSFORMER

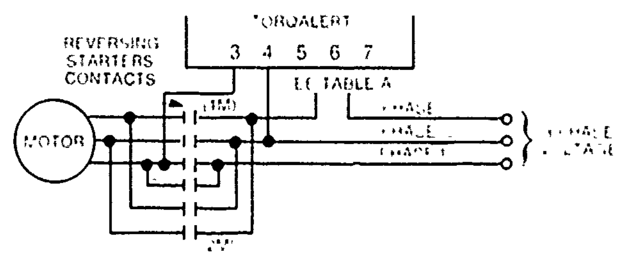


FIG D REVERSING STARTERS

SECTION B — CONTROL CIRCUITS

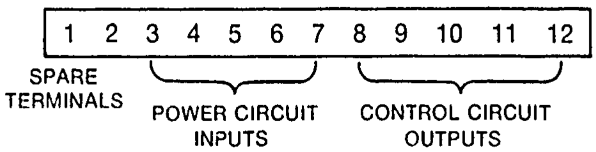


FIG. E

CONTACTS SHOWN IN SIGNAL STATE

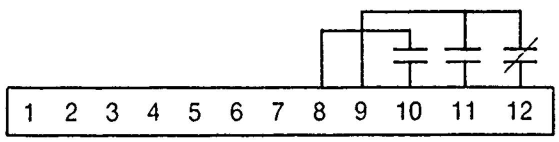


FIG. F

CONTACTS SHOWN IN MONITORING STATE

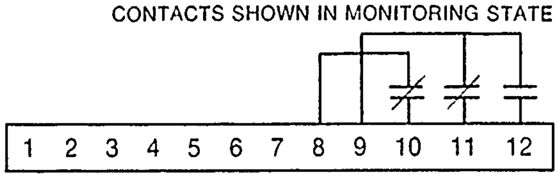


FIG. G

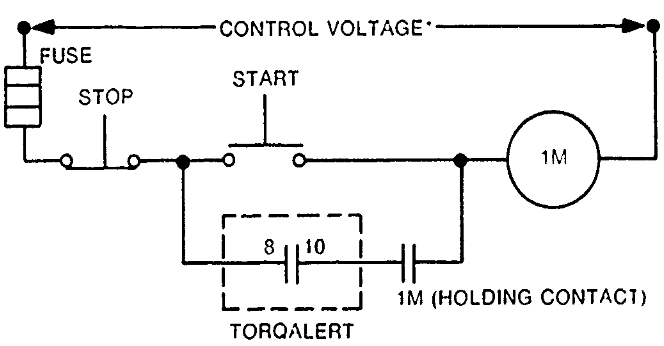
Examination of the TorQalert terminal strip in Figures E, F and G, reveals that terminals 8 through 12 are the output contacts of the relay. It is important to distinguish when the output contact states occur.

In Figure G, the output contacts are shown in the TorQalert monitoring state, — when the unit is sensing the power to the motor. The relay is energized.

When the TorQalert senses an overload of power to the motor, the relay is de-energized and the contacts switch to the signal state (figure F) with the contact signal state shown in figure F, any number of control circuits can be designed to fit the particular application.

To aid the installer with his design, the next few pages contain examples of control circuits. Once the control and power circuits are installed on the TorQalert, it must be calibrated as described in Section C.

EXAMPLE 1 — DIRECT ON LINE

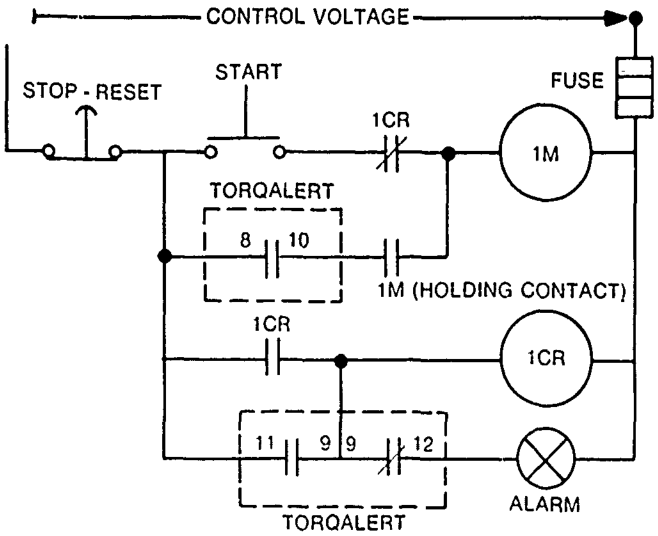


PURPOSE:
To shut down the motor being monitored if any overload of power occurs.

DESCRIPTION: Refer also to Figure B.
Momentary depression of the start button energizes starter 1M, closing its three phase contacts in the power circuit, and the holding contact in the control circuit. Since, the TorQalert is connected after the starter contacts, the relay is energized and its output contact (term 8 and 10) in the control circuit close. The motor starter, 1M, is held through the path containing the TorQalert in the control circuit. An increase in motor power from the preset value (Section C) is detected by the TorQalert in the power circuit and the relay is de-energized, opening the output contact (term 8 and 10). This results in de-energizing the motor starter and the motor is shut down.

**NOTE* — Control voltage is defined as the voltage that is used to energize the coils of starters, relays, timers, etc.

EXAMPLE 2 – DIRECT ON LINE WITH FAULT SIGNAL



PURPOSE:

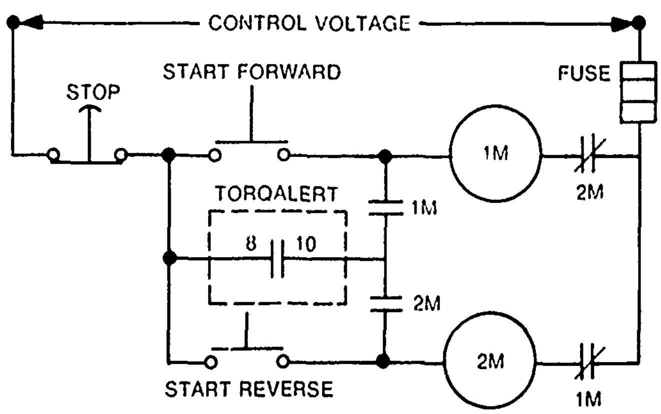
To shut down the motor being monitored and trigger an alarm when an overload occurs.

DESCRIPTION: Refer also to Figure B.

The first half of this control circuit is essentially the same as the direct on line of example 1. Momentary depression of the start button applies the control voltage across the motor starter (1M) closing the three phase contacts of the power circuit. As this occurs, the motor starts and the relay of the TorQalert is energized, closing the contacts across terminals 8 and 10, 9 and 11 and opening the contacts across 9 and 12. The closing of the contact across terminals 9 and 11, energizes an external control relay, 1CR, (supplied by installer), switching its contacts to opposite states than those pictured in the control circuit. The motor starter is now kept energized by the path through terminals 8 and 10 of the TorQalert and its holding contact. When an overload from the preset value (Section C) occurs, the TorQalert relay is de-energized, changing the contacts to their original states shown in the control circuit diagram. The motor starter drops out and the motor is shut down. Since the external control relay, 1 CR, is still energized, its contact completes the circuit to the alarm and the alarm sounds.

Pressing the stop-reset button breaks the circuit to the control relay, 1CR, and resets the control circuit to the original pictured state.

EXAMPLE 3 – REVERSING STARTERS



PURPOSE:

To shut down a two directional Motor when an overload.

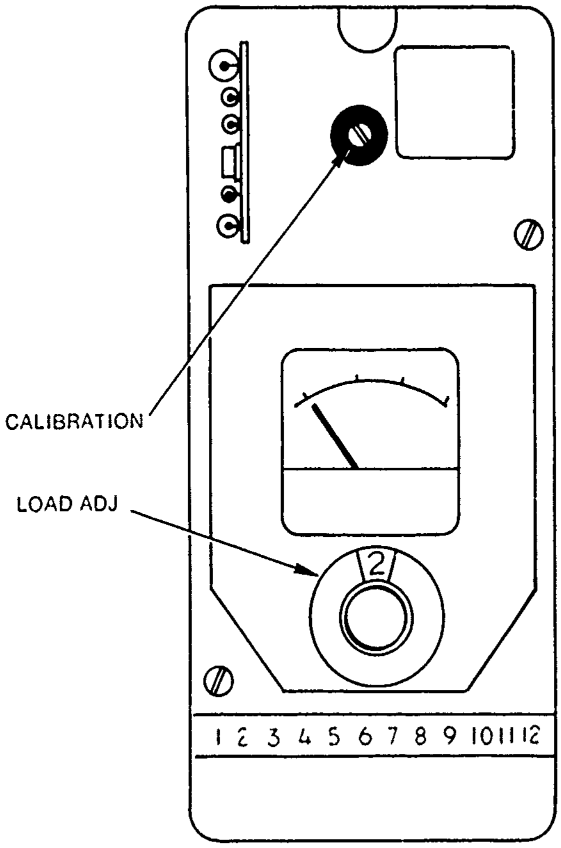
DESCRIPTION: Refer also to Figure D.

The operation of this control circuit is basically two direct on line circuits (example 1). Since the start forward and start reverse cycles are identical, explanation of one cycle also describes the other.

Momentary depression of the start reverse button, energizes starter 2M, closing its three phase contacts in the power circuit and switching the two contacts to opposite states than those pictured in the control circuit. The motor runs in the reverse direction and the TorQalert contacts across terminals 8 and 10 close, providing a holding circuit to starter 2M. Note that the start forward cycle is prevented when the reverse cycle is operating, by the now open 2M contacts adjacent to starter 1M. This same operation applies also to the start forward cycle.

When an overload from the preset value (Section C) in the motor occurs, the relay in the TorQalert is de-energized, opening the contacts across terminals 8 and 10. This breaks the holding circuit to the appropriate starter and the motor is shut down.

SECTION C. CALIBRATION AND LOAD ADJUSTMENT



CALIBRATION PURPOSE:

To match the TorQalert to the motor. This should be done on the first operation only.

LOAD ADJUSTMENT PURPOSE:

To set the TorQalert at the motor's normal working conditions as near to 100% as desired. such that an increase in working load de-energizes the TorQalert relay.

1. Set the *load adj. control* maximum clockwise.
2. Set the *calibration control* maximum counter-clockwise.
3. Start the motor without load. The meter reading should be between 40% to 60%.
4. Gradually turn the *calibration control* clockwise and note that the meter reading decreases to a minimum and then starts to increase. (If the reading does not decrease. interchange the connections between terminals 3 and 4 in the power circuit.)
5. Set the *calibration control* to a minimum reading on the meter.
6. Start the motor at normal load and turn the *load adj. control* slowly counterclockwise until the meter reading reaches 100%. The TorQalert relay should de-energize (Signal State).
7. Turn the *load adj. control* clockwise so that the meter reading is as close to 100% as desired.*

**The TorQalert relay is calibrated to operate when the meter reaches 100%. A setting too close may be pushed past the 100% mark by uncontrollable fluctuations in the voltage supplied to the motor. The maximum stable meter reading can only be found by trial and error.*

In some applications. it may be desired that the motor tolerate a percentage of overload. To do this. the load adjustment control should be set at a lower level. The lower the setting. the greater the load increase required to de-energize the TorQalert relay. For example. if it is desired that the motor tolerate a 20% overload. the meter should be set at 80%.

Formsprag
Sensors • Controls
DANA

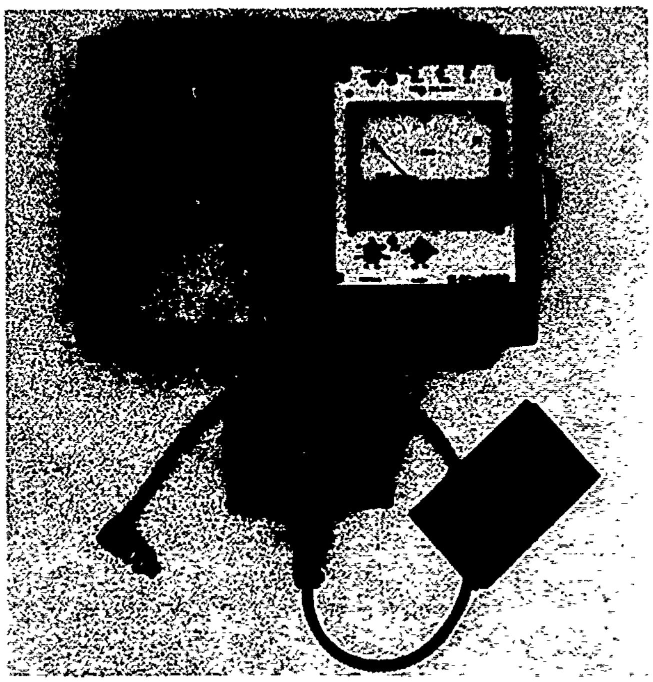
P.O. BOX 778, 26444 GROESBECK HWY.
WARREN, MICHIGAN 48089
TELEPHONE (313) 758-5000, TELEX 230-389

CANADIAN SALES: 17 VALOIS BAY AVENUE
PT. CLAIRE, P.Q. H9R 4B4 CANADA
(514) 695-7620

RFD INSTRUMENT CO., INC.

(512) 285-3385/3386

404 NORTH MAIN • P. O. BOX 548 • ELGIN, TEXAS 78621 • U.S.A.



PATENT PENDING

"PERCENTAGE OF LOAD"

MOTOR & LOAD TORQUE ANALYZER

SERIES PCM2002

FEATURES:

- Two separate inhibit alarm functions with locking adjustment
- Readout in direct percentage of load
- 0 to +70^{o}C Ambient temperature
- Field calibration and alignment
- Automatic lockout/manual reset
- Integrated circuit solid state logic
- Adapts to most motors and rotary loads

GENERAL:

The PCM2002 is a universal motor monitor and control that can be used on single or multiple phase motors, it monitors both motor and load independent of voltage, horsepower, and shaft size. It detects the slip characteristics of the motor with a solid state transducer in close proximity to the rotating shaft. No physical contact, special gears or collars are needed.

The all solid state integrated circuit PCM2002 is designed for the ultimate in reliability. The solid state pickup and shaper provides a noise free signal in most applications. The motor current equivalent is digitally compensated and displayed on a 4 inch meter. An adjustable warning light or horn, also a separate adjustable alarm output for automatic motor shut down is provided if the percentage of load exceeds a preset value.

MODEL OPTIONS:

PCM-2002... Basic unit with two dry contact relays to monitor or control a specific motor or work task.

PCM-2002A.. Basic unit as the PCM2002 with an additional 4-20MA two wire transmitter into 600 ohm.

PCM-2002B.. Basic unit as the PCM2002, but contains a digital readout and BCD coded output.

PCM-2002C.. Basic unit as the PCM-2002, but enclosed in a Class 1, Div. 2 explosion proof enclosure, glass door and Class 1, Div. 2 armor probe.

PCM2002D.. Basic unit as the PCM2002 with a digital steering and control logic to detect changes in torque, make a set count and stop device for another set period of time.

ENGINEERING SPECIFICATIONS:

Power Input..........120 VAC, 5 watts, 50/60 Hz (18 to 30 VDC unregulated 3 watts, special order).

Accuracy.............±.0025% of Full load RPM.

Motor Speeds.........From 200 RPM to 10,000 RPM.

Transducer...........Hermetically sealed Brass/Aluminum head, with cable enclosed in stainless steel armored cable and weather proof connector.

Circuitry............Solid state digital logic with optional relay or solid state output control.

Range................0 to 120% Horsepower, other ranges available.

Inhibit Function I...10 to 90% Horsepower optional 100% scale available, dry, 10 amp, @600 volt relay contacts (optional solid state output available at extra cost).

Inhibit Function II..90 to 120% horsepower optional 100% scale available, dry, 10 amp, @600 volt relay contacts (optional solid state output available at extra cost).

Start................Built in variable time delay from initial start to allow motor to equilabrate. (Please specify when ordering).

Reset................Manual reset and override located on front panel.

Readout..............Special 4 inch jeweled anti-vibration type meter.

Alignment............Front panel adjustable zero, field calibration.

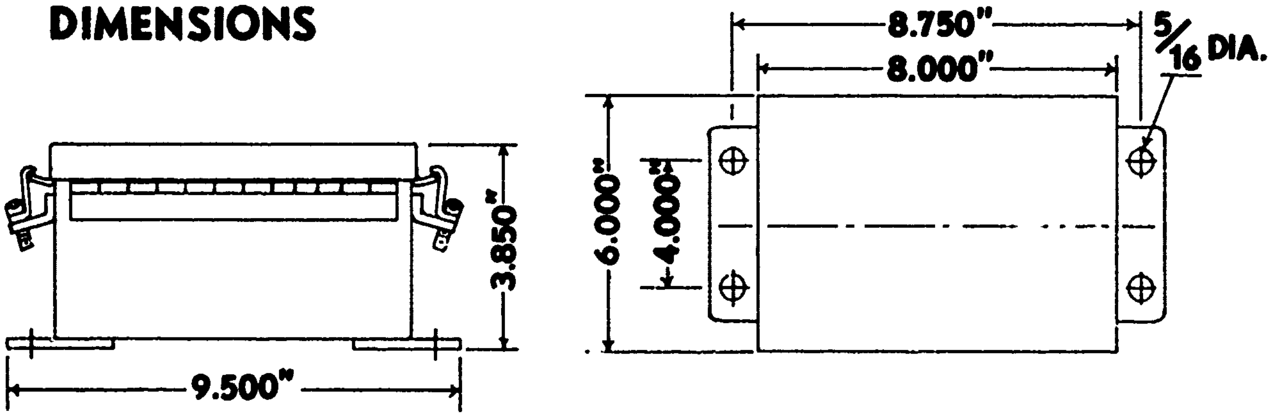
Protection...........Lightning/Transient protected.

Ambient Temperature..0 to 70°C. Optional -20 to 85°C.

Enclosure............14 Gauge steel nema 4, water, dust and splash proof.

Size.................6"x9"x3½" with enclosure. 5"x6"x3" Electronics Module.

DIMENSIONS



NOTE: Specifications subject to change without notice.

RFD Instrument Co., Inc. guarantees the PCM2002 Motor Control Monitor to be free from defects in material and workmanship for a period of one year from date of purchase.

RFD P/N 0036-00J-0001

MOTOR SLIP VERSES CURRENT CHARACTERISTIC

APPLICATION NOTE:

In practical motor overload detection the current parameter is usually utilized as an indication of load conditions. However; due to ambient temperature variations, difficult field installation and set up the current method is sometimes not adaptable and willnot satisfy some applications.

The slip parameter of a motor can be utilized to obtain more information than that available from the current parameter, as shown from the following excerpt and curve.

> [1]"The relationships between power function, efficiency, and current at various partial loads of a typical design B 10-Hp motor are shown in fig. 2-7... The percent of full load slip curve in fig. 2-7 is a straight line between 10 and 110 percent, indicating that slip speed is directly proportional to the horsepower load in this range. This relationship provides an accurate means of estimating loads carried by squirrel-cage induction motors in integral-horsepower sizes... A squirrel-cage induction motor no load speed is slightly less than synchronous speed. In the example in fig. 2-7, the no-load slip is approximately 1 rpm, which is equivalent to 1,799 rpm no-load speed... Between zero load and 100 percent load, motor speed changes only 3 percent in the Nema B motor as illustrated in fig. 2-7. The motor horsepower and motor torque are therefore in a direct relationship...".

By monitoring the motor slip and utilizing the information derived, a reliable parameter is available for monitor and control.

APPLICATIONS PRETAINING TO MONITOR OF MOTOR SLIP:

: To protect high ratio gear reducers and spur gears.

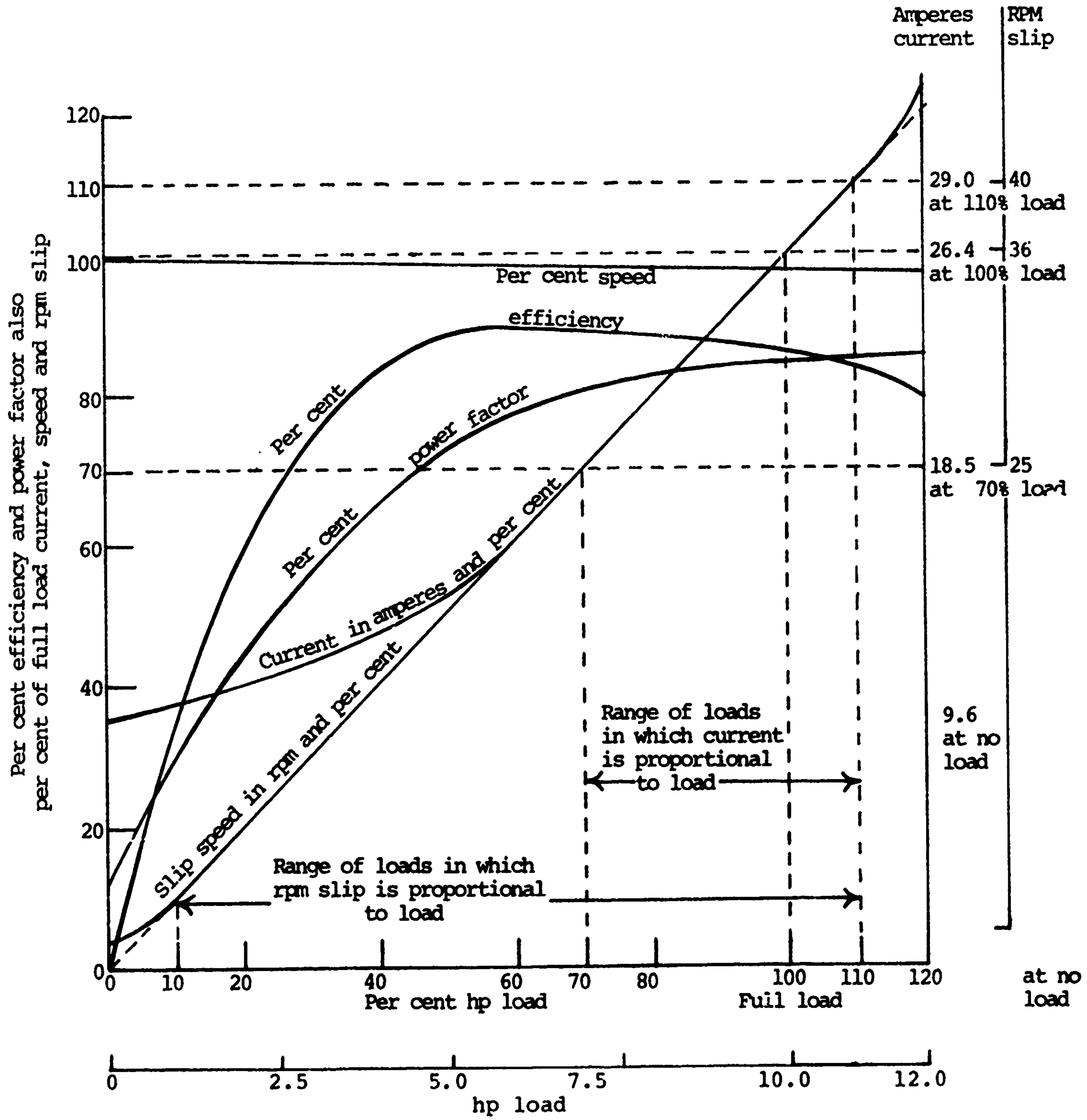
: To monitor and control pumping slurrys or corrosive materials.

: To monitor and control centrifugal blowers.

: To monitor and control for direct computor interface with analog or digital readout of most motor types and loads used today.

[1]"From Motor Selection and Application," by Charles C. Libby, Copyright 1960, used with permission of McGraw-Hill Book Company.

[2]Fig. 2-7. Performance curves of typical 10-hp 1,800-rpm Design B squirrel-cage induction motors, rated voltage and frequency applied.



[2]"From Motor Selection and Application," by Charles C. Libby, Copyright 1960, used with permission of McGraw-Hill Book Company.

Applications:

Municipal Sewage and Water Treatment Plants:

1. Utilized on clarifier drives to monitor the motor and gear reducer, allowing the operator to detect less than a 100 lb. load and stop a triple 20,000:1 gear reducer before any physical breakage or malfunction can occur.
2. Utilized in conjunction with an RFD TCM4001 temperature indicator to monitor the motor bearing temperatures or blower outlet temperature (PCM2006) plus monitor the load and give a direct readout in CFM. The unit also provides surge and over load protection and control for the complete blower installation.
3. Used on thickner drives to detect stoppage of the gear drive assemblies and inhibit operation if a malfunction occurs.

Industrial Applications:

1. Bakery industry to monitor and control the mixers, using the PCM-2002A to batch mix bread dough and batter to a set consistency or viscosity.
2. Pulp industry monitor and control slurry pumps along with the temperature parameter of the bearings for proper operation.
3. Petroleum industry to monitor and control oil well heads utilizing the PCM-2002D as a pump off controller.
4. Utilized by OEM motor manufacturers as an in-house test set for the monitoring and checkout of new induction motors. By applying the PCM-2002B to a checkout stand, the manufacture has a coded BCD output to be interfaced directly to his computor.
5. Rendering works industry to monitor and control the consistency of the cooked meat as it is transferred through the rotary cooking ovens.

The applications noted are but a few possible applications of this device, they are not limited to just induction motors. Wherever there is a job to be done and rotary work over 1000 RPM is doing the initial work, whether it be on a diesel engine on board ship or on a generator at a power plant, (synchronous motors and conditions not applicable), if a slip of at least .5% is discernable, we can apply this device and accomplish the task of monitoring and controlling its load.

<u>How to Calculate Motor Slip:</u>

Motor or work slippage is the difference in turns at no load and the turns at full load. Example: If a motor has a nameplate full load rating of 1750 RPM, then the synchronous speed or no load speed for practical purposes would be 1 RPM less than 1800 or 1799 RPM.

```
 1799 no load
-1750 full load
   49 RPM slip from 0 to 100%
```

Percentages of slip can be said that it is the slip divided by the no load speed.

$$\frac{49 \text{ RPM}}{1799 \text{ RPM}} = .0272 \text{ or } 2.72\%$$

To calculate the times involved, first take 1799 and divide by 60 to put the factor in revolutions per second.

$$\frac{1799}{60} = 29.98333333$$

Then to time

$$\frac{1.00000}{29.98333333} = .0333518621 \text{ sec. or } 33.352 \text{ milli-sec.}$$

Then find

$$\frac{1750}{60} = 29.16666667$$

Then to time

$$\frac{1.000000}{29.16666667} = .0342857142 \text{ sec. or } 34.286 \text{ milli-sec.}$$

Take:

34.286 milli-sec. Full load speed
-33.352 milli-sec. No load speed

.934 milli-sec. or 934 micro-seconds difference between 0 and 100% load on this particular motor. On a 75 to 125% scale, this puts 467 micro-seconds as the standard slip in time. Because the slip is linear, we can shift it from 5 to 120%. The motor will then change from 34.0525 milli-seconds to 34.519 milli-seconds from 75 to 125% of load

To find the "A" time, proceed as follows:

$$\frac{467 \text{ micro-seconds}}{2} = 233.5 \text{ micro-seconds}$$

100% time of 34.286 milli-seconds or time "B"

34.286 100% time "B"
+ .2335 50% of time difference derived at calculation above

34.5195 milli-seconds time "A"

34.286 100% time "B"
- .2335

34.0525 milli-seconds time "C"

PCM2002 INSTALLATION AND OPERATION INSTRUCTIONS

Unpack the PCM2002 and transducer assembly. Inspect for any shipping damages. The shaft or coupling to be monitored must be a ferrous material for proper operation. The PCM2002 transducer detects a void or difference in ferrous material and this produces a resultant signal that is measured against an internal standard.

1. **Utilizing the universal bracket that is furnished with the PCM2002 mount the transducer assembly in a close proximity to the rotating shaft. (NOTE: The transducer will mount in any position and is impunitive to oil, dirt, and water).**

2. **Reference Figure 1, utilizing the feeler gauge supplied with the PCM2002, adjust the transducer as shown in figure 1.**

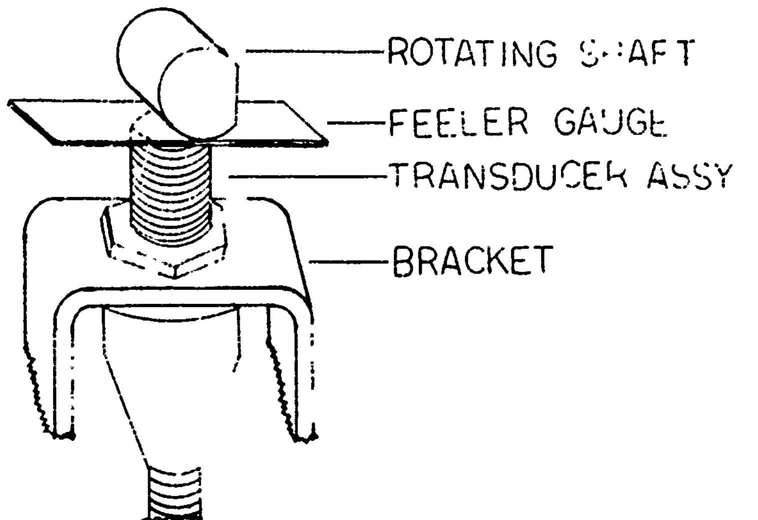


FIG. 1

3. **Insure your PCM2002 is set up for the proper speed and Nema Type Motor as you are installing it on. This is a factory setup and should not be attempted in the field because of proper test facilities.**

4. **Mount the PCM2002 securely to a solid structure and connect as shown in figure 2.**

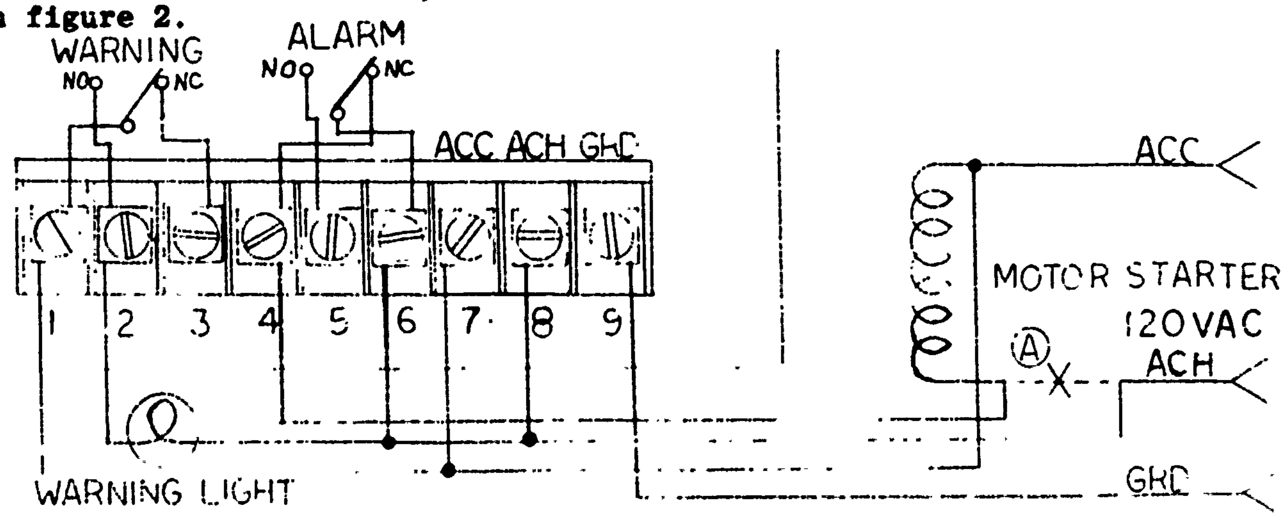


FIG. 2

Disconnect motor starter at point A and reconnect as shown for control operation.

5. Unlock the front panel screw driver lock nuts and preset the warning and alarm adjustments to a full CW position.

6. Apply power to motor from HOA or circuit breaker, turn on PCM2002 (NOTE: there is a 20 second delay before the control circuit is activated).

7. With a clamp on type ammeter or equivalent attach pickup on one of the AC leads going to the motor.

8. With the motor connected to the load, apply power and observe the ammeter reading. (NOTE: lock ammeter reading or jot reading down) also with a voltmeter measure the applied voltage across the motor.

9. Shut off motor and examine the motor identification plate, Note the voltage verses current as applied to your particular installation, Example:

Voltage	Amps	RPM
115/230	6.4/3.2	1750

NEMA TYPE B

10. Calculate the 100% load figure as follows from the motor identification plate.

Voltage X Amps=Power in watts

$$E_1 X I_1 = P_1$$

11. Calculate the actual motor load, using the measured voltage as applied (E_2) and using the current reading (I_2) derived in step 7, multiply as in step 10.

Voltage X Amps=Power in watts

$$E_2 \; X I_2 = P_2$$

12. To derive the correct setting of the meter zero R-8 on the PCM2002, calculate as follows: Divide the motor plate power into the measured power figure.

$$P1 \overline{\big) \; P2}$$

13. Start the motor and turn on the PCM2002, with the motor running adjust the front panel adjustment R-8 for the proper percentages of load as derived in step 12. The other adjustments should not be attempted unless the proper test instrumentation is available. Reference the PCM2002, alignment and maintenance manual.

14. Using information derived in step 9 through 12, calculate the warning and alarm set point and adjust for desired warning and alarm condition.

How to calculate horsepower load on the Gear Reducer Drive Motor.

$$HP= \frac{\text{Torque load (inch lbs.) x RPM (Motor)}}{63,025}$$

OR

$$HP= \frac{\text{Torque load (foot lbs.) x RPM (Motor)}}{5252.0833}$$

Efficiency= Hp out/Hp in

$$\text{Required input torque}= \frac{\text{Torque out}}{\text{Ratio} \;\Big/\; \text{Eff.}}$$

Utilizing the 75 to 125% or the 20 to 120% of load scale, the slip is linear with horsepower.

EXAMPLE: We have a 1725 rpm full load .5 Hp motor driving a 20,000:1 gear reducer, on a 50 ft. diameter clarifier, with an average of 7 lb. per ft. of sludge load, with an overall efficiency of 60%. The PCM2002 has a 75 to 125% of load scale. What percentage of load change will be observed on the meter with a 1 lb. per foot build up of sludge on the scraper arm?

First we know slip is linear with horsepower so 75 to 125% of scale is 50% of the total horsepower on the motor. Each division is equal to .005 horsepower per division or .0025 horsepower per percent of scale. (.5 Hp ÷ 2 = .25 Hp per 50 divisions or each division equal to .005 Hp at the motor shaft).

Next we must calculate the loading on the clarifier output drive.

$$\text{Hp of output scraper drive}= \frac{\text{Torque load (inch lbs.) x RPM (output Drive)}}{63.025}$$

OR

$$\text{Hp of output scraper drive}= \frac{\text{Torque load (ft. lbs.) x RPM (output Drive)}}{5252.0833}$$

With a 20,000:1 reducer on a 50 ft. diameter clarifier and a nominal 7 lb. per foot load of sludge. $(3 \times D^2 \times 7)$= Torque required $3 \times (50)^2 \times 7$= 52500 inch lbs. of torque at the scraper proper.

Next we calculate total Hp at the motor shaft with a 60% efficiency (1725 RPM ÷ 20,000= .0875 RPM).

$$Hp= 52500 \times .0875= .0728 \text{ Hp}$$
$$\underline{\times 1.666}$$
$$.12 \text{ Hp}$$

(60% eff.= factor 1.666)

We can say that at 7 lb. of sludge on a 50 ft. diameter clari-fier tank, operated by a 20,000:1 gear reducer with an effi-ciency of 60% and 1725 RPM motor the required input horsepower will be .12 Hp, we will align this on the PCM2002 at the 100% point with R-8.

The next step is to arbitrarily select a additional loading such as 1 lb. per foot and recalculate the load for 8 lbs. per foot of scraper using the formulas above.

$3 \times (50)^2 \times 8 = 60{,}000$ inch lbs. of torque now at the scraper.

$$Hp = \frac{60{,}000 \times .0875}{63{,}025} = .0833 \text{ Hp}$$

$$\begin{array}{r} .0833 \text{ Hp} \\ \times 1.666 \\ \hline .1388 \text{ Hp} \end{array}$$

$$\begin{array}{rl} .1388 & \text{Hp with 8 lbs. per foot on scraper} \\ -.1200 & \text{Hp with 7 lbs. per foot on scraper} \\ \hline .0188 & \text{Hp increase with 1 ft. of sludge on the scraper} \end{array}$$

We then calculate the percent of increase in horsepower loading .0188 ÷ .5 Hp= 3.76% increase in Hp at the motor. Relating this to scale change of .005 Hp per division the meter will move up scale 3.76 division, (.0188 ÷ .005=3.76 Div.) or a total scale deflection of 7.52%. With a normal load increase of 1 lb. per foot on the scraper in a 50 ft. clarifier the torque analyzer will go up scale 3.76 divisions or 7.52%.