300

RECEIVED BY DTIC DEC 22 1970

**Kansas City
Division**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TRANSFER MOLDING
CLOSE TOLERANCE
PARTS

BDX-613-166

THIS DOCUMENT CONFIRMED AS
UNCLASSIFIED
DIVISION OF CLASSIFICATION
BY JH Kahn lamh
DATE 1/5/71

November, 1970

Prepared by:
R. J. Hishaw
Department 835

MASTER

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Technical Communications

**Kansas City
Division**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

fy

This report was

Prepared by:

R. J. Hishaw
D/835

Approved by:

R. W. Klee
D/835

THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

A prime contractor for the Atomic Energy Commission

Contract Number AT(29-1)-613 USAEC

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Atomic Energy Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

ABSTRACT

Visual defects related to transfer-molded parts of epoxy and diallyl phthalate (DAP) compounds are discussed. Included are sequential photographs taken from high-speed motion pictures made of the flow patterns which occurred in a variety of cavity configurations. The films and direct observation were made possible by a special fused quartz lens, or viewing window, installed in the wall of the mold. The monitored flow characteristics provide the bases for the conclusions.

CONTENTS

Section		Page
1	SUMMARY	1
2	DISCUSSION	3
	TEST SETUP	3
	MOLD DESIGN.	7
	INITIAL TEST FILMING	7
	EVALUATION OF FILMS	9
	FUTURE ACTIVITY.	17
	RECOMMENDATION	17

ILLUSTRATIONS

Number		Page
1	Cutaway of Mold	4
2	Lens and Lights (Polaroid)	5
3	High-Speed Photo Test Setup (Polaroid)	5
4	Observation Test Setup (P-59767)	6
5	Arrangement of Lighted Quartz Lens and Interchangeable Cavity (Ejected) (P-59768).	8
6	Flow Pattern in Round Cavity With DAP Entering From Single Rear Gate and Forming Around Simple Insert Arrangement (P-64494, P-64485, P-64492, P-64493, P-64487, P-64491)	10
7	Flow Pattern in Round Cavity With DAP Entering From Single Half-Round Gate and Forming Around Large Insert (P-64592, P-64594, P-64606, P-64605, P-64591, P-64597)	11
8	Flow Pattern in Round Cavity With DAP Entering From Opposing Half-Round Gates and Forming Around Two Inserts (P-64603, P-64601, P-64604, P-64598, P-64602, P-64608)	12
9	Flow Pattern in Round Cavity With DAP Entering From 90-Degree Gates and Forming Around Simple Insert Arrangement (P-64473, P-64496, P-64495, P-64489, P-64486, P-64476)	13
10	Flow Pattern in Rectangular Cavity With Epoxy-Glass Compound Entering From Opposing Half-Round Gates and Forming Around Complex Insert Arrangement (P-64484, P-64490, P-64488, P-64475, P-64474)	14
11	Flow Pattern in Rectangular Cavity With DAP Entering From Single Rear Gate and Forming Around Complex Insert Arrangement (P-64478, P-64479, P-64480, P-64481, P-64482, P-64483)	15

12	Flow Pattern in Rectangular Cavity With DAP Entering From Multiple Gates and Forming Around Complex Insert Arrangement (P-64607, P-64593, P-64595, P-64596, P-64600, P-64599).	16
----	---	----

Section 1

SUMMARY

The objective of this project is to reduce or eliminate defects affecting the quality of parts transfer-molded from thermosetting compounds. Investigations during this fiscal quarter related to such defects as flow lines, knit lines, poor flow around inserts, and fiber orientation.

To permit analysis of these defects, a mold with interchangeable cavities and a transparent wall, or lens, was conceived. As the various cavity configurations were filled with epoxy or diallyl phthalate (DAP) compounds, the resulting flow patterns were observed and filmed with a high-speed camera.

Despite the problems encountered with initial filming, including damage to the lens in the mold and poor camera control, twelve films were completed. Examination of the films revealed the following.

- The best flow patterns are formed with soft, slow-cure compounds.
- Positioning gates so that the molding material enters the cavity in the area of greatest volume promotes the best pressure for flowing the compound around inserts.
- Opposing gate positions cause knit lines, even in the best test specimens molded with such an arrangement.
- Multiple gates seldom fill simultaneously, especially in small parts, and should therefore be avoided.
- Vents should be placed opposite the gates when insert patterns are involved and when DAP is the molding compound. If either of these conditions does not exist, venting should be located along the periphery of the cavity in areas adjacent to gates.
- Vent holes for epoxy compounds can be smaller than those used for DAP compounds and should be placed in areas adjacent to gates.

Further investigation should be made into the effects of gate size, vent size and cavity depth on flow characteristics.

Studies of the flow patterns of molding compounds will continue into the next quarter. For this work, the purchase of a camera with a shutter-type exposure mechanism, shutoff control, and a speed variable from 100 to 400 frames per second would provide better film quality, limit film waste, reduce viewing time, and increase usable frame space.

Section 2

DISCUSSION

The problems encountered when molding compounds flow into and fill a cavity are as varied as the configurations of transfer-molded parts. Defined below are typical part defects.

- Knit line: An area of defective strength, and usually defective appearance, caused when two or more fronts of material flow together and join improperly.
- Flow line: Visible mark in the molded part caused by solidification of a flow pattern at, or near, the gate area of the mold cavity.
- Flow pattern around inserts: A combination of flow lines and knit lines in proximity to inserts in the mold cavity.
- Fiber orientation: The direction of a fiber filler in the mold cavity, normally relative to gate position.

TEST SETUP

A mold with a transparent wall (see Figure 1) was conceived which permitted direct observation of the molding material as it entered and filled the cavity. The mold was so designed to accommodate interchange of various cavity configurations and insert patterns.

The several glass companies consulted advised the use of fused quartz for the transparent wall. Fused quartz could withstand temperatures of 360°F and pressures of 500 psi and provide a resolution of 200 lines per millimeter to assure the optical clarity required for observing and filming the molding cycles. With the fused quartz window, the parallelism runout attained between viewing surfaces was optically flat at 0.0002 inch. The size of the window is 2.5065 by 2.5065 by 4.500 inches.

Test mockups of the lens were made to evaluate lighting, resolution, and camera setup. Conventional flood lights were bulky, caused reflections, and failed to produce the required light intensity. The desired flexibility and balance in the lighting setup was provided by the two quartz-iodide light sources shown in Figures 2 and 3. Fiber optic tubes were used to concentrate the illumination from these sources (5000 footcandles) on the area of the subject. The observation test setup is shown in Figure 4.

Text continued on page 7.

Figure 1. Cutaway of Mold

Figure 2. Lens and Lights

Figure 3. High-Speed Photo Test Setup

Figure 4. Observation Test Setup

MOLD DESIGN

The metrology department was consulted on the problem of fitting the glass to the steel mold. The different expansion coefficients for the two materials were set at 0.35×10^{-6} in./in./°F for the lens and 6.5×10^{-6} in./in./°F for the mold (the "book value" of tool steel). The dimensions calculated for fitting the lens in the mold at room temperature were reduced to prevent the loose fit, poor support, and excessive flashing that would otherwise result at molding temperature (300°F). Lens removal was required after each molding run to prevent damage to the glass as a result of the shrinkage in the mold which occurs during the cooling period.

A taper block was included to provide the interchangeable cavity feature. Repeatable positioning of the cavity in the mold was made possible by attachment of the taper block to each of the various cavity configurations.

One of the interchangeable cavities is shown (ejected) in Figure 5.

INITIAL TEST FILMING

Attempts were first made to coordinate camera speed with cavity fill times. Depending on the material used, the transfer pressure, preheat, and volume of the cavity, film time varied from approximately 11.5 to 20 seconds. Two hundred feet of 16mm film, at 40 frames per foot, was used for each shooting. By means of a variable transformer (Figure 3), camera speeds were reduced consistent with the time required to fill the mold cavity.

Attempts were also made to get a faster fill (12 to 18 seconds). The objective was to assure that the film did not terminate before the cavity filled or that the cavity did not fill while excess footage was expended. Since one second of shooting time is the equivalent of 16 to 29 seconds of projecting time, it was important to match, as nearly as possible, fill time to film time. By so doing, available footage could be used to record the flow pattern characteristics which occur during the transfer molding process.

While the above efforts were being made to control camera and fill speeds, two types of lens damage occurred. The first was corner and edge breakage which was the result of both mishandling and flashing between interfacing surfaces of glass and metal, particularly in the area of the upper lens surface and the hold-down plate. To prevent such damage, the cavities were reworked to change the runners and thus prevent the molding material from crossing the glass-to-metal interface.

Figure 5. Arrangement of Lighted Quartz Lens and Interchangeable Cavity (Ejected)

The second type of lens damage was caused by adhesion of the molding material to the glass surface. Removal of the material caused pitting of the glass, and subsequent molding caused the pits to grow even larger, especially when epoxy compounds were used. Consequently, until the condition is corrected, only DAP molding compounds will be used. Also, a clear mold release is being applied in amounts small enough to avoid distortion in the films.

EVALUATION OF FILMS

Approximately 12 films have been made, excerpts from which are included in Figures 6 through 12. Examination of the films revealed the following.

- The best flow patterns are produced with soft, slow-cure compounds. Apparently the lower viscosity of these compounds permits complete flow before the material has begun to cure.
- Placing of gates to allow the material to enter the cavity in the area of greatest volume (Figures 6 and 11) seems to promote the pressure required for flowing the compound around inserts. Such an arrangement is especially effective when DAP compounds with long glass fibers are used. When inserts are necessary to part geometry, they act as flow barriers restricting the direction of flow and thus cause some pressure between the gate and the insert itself. Because thermosets have a continuously increasing viscosity with respect to time and temperature, this method is most helpful in small volume parts where short flow times are required.
- As is the case with any multiple gate arrangement, opposing gates are a major cause of knit lines (see Figures 8, 10, and 12). Such gates seldom fill simultaneously and should be avoided when possible. Multiple gating should be limited to parts with volumes so great that fill times are otherwise prolonged.
- In cases where long glass fiber-filled DAP compounds are to be flowed around inserts, venting should be placed in areas of final flow. This arrangement is required since the areas that fill last are usually blocked from direct gate flow by inserts. When no insert pattern is used, venting should be in areas adjacent to the gate since these fill last. This type of venting is also suited to the glass-filled epoxy compounds. Since they are less viscous than the DAP materials, they fill first in the direction of flow.

Text continued on page 17.

Figure 6. Flow Pattern in Round Cavity With DAP Entering From Single Rear Gate and Forming Around Simple Insert Arrangement

Figure 7. Flow Pattern in Round Cavity With DAP Entering From Single Half-Round Gate and Forming Around Large Insert

Figure 8. Flow Pattern in Round Cavity With DAP Entering From Opposing Half-Round Gates and Forming Around Two Inserts

Figure 9. Flow Pattern in Round Cavity With DAP Entering From 90-Degree Gates and Forming Around Simple Insert Arrangement

Figure 10. Flow Pattern in Rectangular Cavity With Epoxy-Glass Compound Entering From Opposing Half-Round Gates and Forming Around Complex Insert Arrangement

Figure 11. Flow Pattern in Rectangular Cavity With DAP Entering From Single Rear Gate and Forming Around Complex Insert Arrangement

Figure 12. Flow Pattern in Rectangular Cavity With DAP Entering From Multiple Gates and Forming Around Complex Insert Arrangement

The above findings further indicate that material reaches some internal pressure when it is forced through the gate: it is compressed on approach and decompressed in transition. The result is fiber orientation and a tendency of the material to overheat before flow. As typified by the flow patterns in Figures 1 and 5, the volume of material being molded is more nearly related to the area of the gate cross section than to the area of the runner. Because the material that enters the runner first may remain at the gate, only a small stream of the remaining material can flow through its center. As a flash ring relieves pressure in compression molding, the vents in the transfer molding cavity provide an escape for trapped air to permit smooth, unrestricted flow of the material.

FUTURE ACTIVITY

Investigation will continue during the next quarter into the effects of gate and vent sizes on flow characteristics and fiber orientation. Additional mold inserts will be fabricated to investigate flow patterns in cavities with different cavity depths.

RECOMMENDATION

The purchase of a new camera is being considered to improve film quality. The minimum film speed of the Fastax camera now used is 400 frames per second, which is excessive for filming molding cycles. Also, the rotating prism exposure mechanism of the Fastax camera chops both the upper and lower sections of the frames. Since the camera has no shutoff control, an entire roll of film must be shot before the camera will stop. These problems could be solved by the purchase of a camera with a shutter-type exposure mechanism, a stop-action feature, and a speed control variable from 100 to 400 frames per second.